JOURNAL of THE IRON AND STEEL INSTITUTE

VOL. 176 PART 3

MARCH 1954

PUBLISHED MONTHLY

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THE IRON AND STEEL INSTITUTE

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EDITORIAL AND ADVERTISEMENT OFFICES 4 Grosvenor Gardens, London, S.W.1 · SLOane 0061
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SUBSCRIPTIONS
Members Free : Extra Copies 7s. 6d. each
Non-Members : £5. 0. 0 per annum
Single Copies 10s. each

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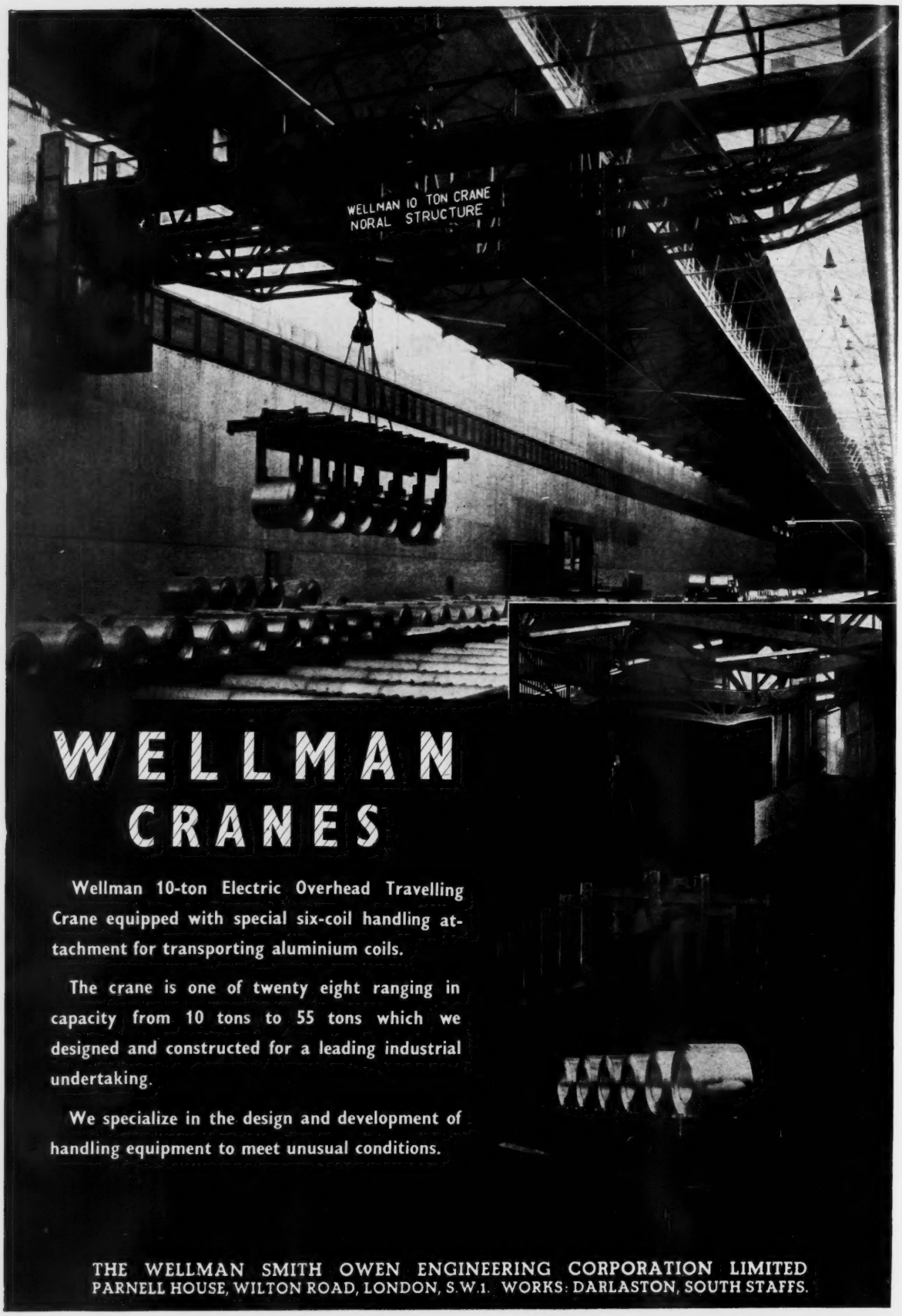

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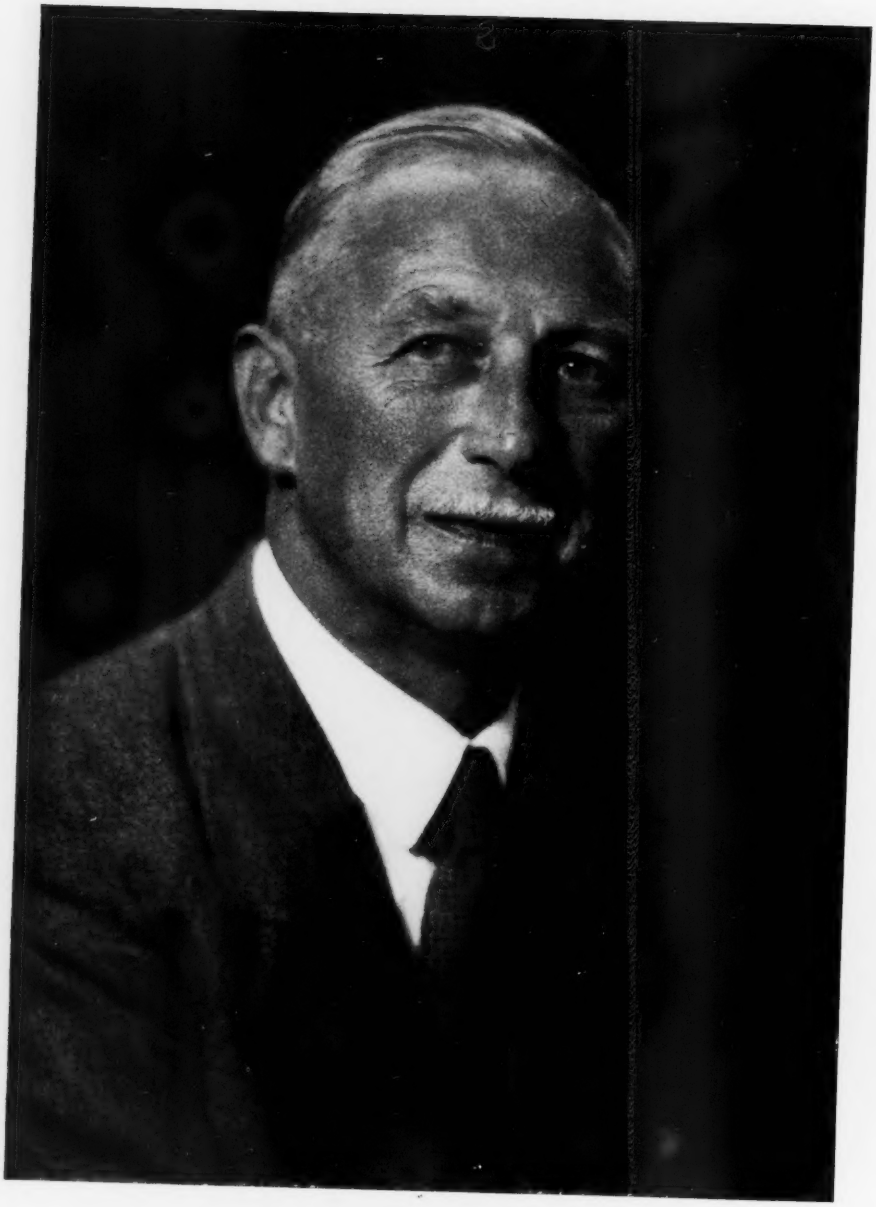
H. ALLISON, B.Sc. (Tech.), F.I.M.

HARRY ALLISON was born in Manchester in 1901. He was educated at Manchester Central High School for Boys and at the College of Technology, Manchester University, where he was awarded the degree of B.Sc. (Tech.) in 1922.

Mr. Allison commenced his career as a metallurgist in the Research Department of Metropolitan-Vickers Electrical Company, Limited. In 1943 he transferred to the manufacturing side of the Company, taking up the appointment of Heat Treatment Engineer.

President of the Manchester Metallurgical Society for the session 1952-53, Mr. Allison was elected a Member of The Iron and Steel Institute in 1928. He was elected a Fellow of the Institution of Metallurgists in 1946.



H. Allison, B.Sc. (Tech.), F.I.M.
Honorary Member of Council, 1952-53

PROCEEDINGS OF THE INSTITUTE

REPORTS OF COUNCIL - OFFICIAL NOTICES

AUTUMN GENERAL MEETING, 1953

THE AUTUMN GENERAL MEETING of THE IRON AND STEEL INSTITUTE was held on Tuesday and Wednesday, 24th and 25th November, 1953, at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1. The President, Mr. JAMES MITCHELL, C.B.E., was in the Chair, except during the afternoon of the first day, when his place was taken by Mr. RICHARD MATHER, Past-President.

Sessions were held from 2.15 P.M. to 5.15 P.M. on the Tuesday and from 9.45 A.M. to 1.15 P.M. on the Wednesday. Buffet luncheons were provided in the Library of the Institute on both days. A Symposium on Sinter was held on the afternoon of Wednesday, 25th November, and all day on Thursday, 26th November.

The Minutes of the previous Meeting, held in London on Thursday, 30th April, and Friday, 1st May, were taken as read and confirmed.

ABSENCE OF THE PRESIDENT

The **Chairman** (Mr. Richard Mather) apologized on behalf of the President, Mr. James Mitchell, who was unable to attend the meeting.

MEETING IN THE NETHERLANDS

The **Chairman** said that the Meeting of the Institute in the Netherlands had been a very successful overseas occasion. On behalf of the Council he expressed thanks to all the Institute's friends in the Netherlands, who had done so much to make the visit a success. He assured them of the gratitude of the Institute for the hospitality and kindness with which they had received the Members and their ladies.

The Chairman of the Reception Committee, Mr. Ingen Housz, had accepted the Council's invitation to become an Honorary Vice-President, in which office he would strengthen the organization of the Institute. The Council greatly appreciated all that had been done by him, and by Mrs. Ingen Housz, who acted as Chairman of the Ladies Committee.

WELCOME TO MEMBERS AND VISITORS

The **Chairman** welcomed the Members and visitors on behalf of the Council. He especially welcomed Principal Edwards after a long interval, and recalled the time when he had been a very frequent attender and participant in the discussions at the Meetings of the Institute. He also extended the Institute's welcome to the representatives of Members in other countries.

Many of the visitors had come primarily to take part in the Symposium on Sinter, at which a particularly important and valuable selection of papers was to be presented. The Council greatly appreciated the help given to the Institute by the authors of the papers in presenting important facts, setting out the big advances that had been made, and indicating the lines for further advances.

LEASE OF OFFICES

The **Chairman** announced that the Institute had recently had an opportunity of purchasing a 60-year lease of 4 Grosvenor Gardens. The lease on which they had started the occupation of this building was due to expire in about two years' time, and this fact had been a source of concern to the Council. Formalities in connection with the purchase of a 60-year lease had now been completed and continuity of occupation of that admirably suitable building was ensured.

This had been possible only as a result of substantial grants from a large number of companies in the industry who had willingly helped the Institute in the financial problems involved, and a lease had been purchased on a considerably lower rent than in the past. The Council intended that the saving in rent, plus some additional amount, should be set aside each year to ensure that when the new lease expired, the Institute would be in a position to meet the situation out of its own resources. The Institute was deeply grateful to the firms who had helped them in this very important matter.

MEETING IN SWEDEN

The **Chairman** reminded Members that an invitation from Jernkontoret to hold a meeting in Sweden in 1954 had been accepted. An outline of the programme had

already been published in the *Journal*. The full dates were from 5th to 19th June, 1954, but shorter programmes would be available for those who were unable to stay the whole of the time. He assured their Swedish friends how much they were looking forward to this meeting. Their Swedish colleagues in the iron and steel industry were very hospitable and had much of real interest and enlightenment to show them.

ELECTION OF PRESIDENT

The **Chairman** announced that the Council had recommended that The Hon. R. G. Lyttelton, Vice-President, be elected President, to take office at the Annual General Meeting in 1954 to serve for one year.

Mr. Lyttelton had worked for many years in the interests of the Institute. He had been for a long time its Treasurer, during a particularly difficult financial period, and the Institute owed him a great debt of gratitude for his work in that very important office. The Members of the Council were confident that the credit and standing of the Institute would be enhanced during his Presidency.

The recommendation was agreed to unanimously.

ANNOUNCEMENTS

Changes on the Council

The **Secretary** (Mr. K. Headlam-Morley) reported the following changes on the Council since the last General Meeting in April, 1953:

Hon. Vice-President—Mr. A. H. Ingen Housz

Member of Council—Mr. C. H. T. Williams

Hon. Members of Council (during their periods of office)—

Mr. A. W. Ellis, President of the Ebbw Vale Metallurgical Society, in place of Mr. W. D. Jenkins.

Mr. Henry D. Ward, President of the Leeds Metallurgical Society, in place of Dr. N. J. Petch.

Mr. H. J. Miller, President of the Liverpool Metallurgical Society, in place of Mr. R. S. Brown.

Mr. D. L. Blewett, President of the Swansea and District Metallurgical Society, in place of Mr. H. N. Bowen.

Retiring Members of Council

The following were due to retire at the next Annual General Meeting and are eligible for re-election:

Vice-Presidents—Mr. N. H. Rollason, Sir Charles Bruce-Gardner, Bt., and Mr. C. R. Wheeler, C.B.E.

Members of Council—Mr. H. Boot, Mr. S. Thomson, Mr. E. T. Judge, Mr. E. J. Pode, and Mr. B. Chetwynd Talbot.

Andrew Carnegie Scholarships

The following awards have been made since the last General Meeting:

Mr. S. W. K. Shaw (Sheffield University): £100 to assist research on carbide formation at 700° C. in low-carbon chromium–vanadium steels.

Mr. J. Wilcock (Liverpool University): £100 to assist research on the influence of sulphur and manganese on the graphitization of the iron–carbon–silicon system

Mr. S. V. Radcliffe (Liverpool University): £50 to assist research on the isothermal transformation of austenite in the region of the change from pearlite to bainite formation.

AFFILIATED LOCAL SOCIETIES

The **Secretary** announced that, with a view to encouraging the Affiliated Local Societies, the Council had declared that all the Affiliated Local Societies were kindred societies under Bye-law 21, and had fixed the subscription of Members of the Institute who were also Members of these Societies at the reduced rates of £1 11*s.* 0*d.* for Associate Members, as at present, and £3 13*s.* 6*d.* for Ordinary Members, with effect from 1st January, 1954. The result of this action was that Members of Affiliated Local Societies who were not already Members of the Institute of Metals or of the Institution of Metallurgists would, from 1st January, 1954, pay subscriptions at the reduced rates applicable to Members of these two Institutes.

ELECTION OF MEMBERS

Mr. E. Taylor Austin (Mostyn) and Mr. D. I. King (London), who had been appointed scrutineers of the ballot, reported that the following had been elected:

Members

Abe, Nobuo, B.Eng. (Japan); **Apold,** Arne (Oslo, Norway); **Astier,** Jacques Emile (Paris); **Bailey,** William Howard, A.Met., A.I.M. (Sheffield); **Barlow,** John P. (Birmingham); **Barnaby,** Robert (Sheffield); **Biggart,** William Gibson, B.Sc., T.D. (Glasgow); **Both,** G. J. J., jun. (Utrecht, Holland); **Boyes,** Ronald Henry (Rugby); **Braaten,** Erling Thorstein (Oslo, Norway); **Broadbent,** Peter, B.Sc. (Huddersfield); **Bunton,** John Darrah, A.I.M. (Bromsgrove); **Carr,** Laurence H. (East Chicago, Ind., U.S.A.); **Chamberlain,** Frank Arthur (London); **Christiansen,** Bent, M.Sc. (Frederiksvaerk, Denmark); **Coghlan,** Humphrey St. John (Leeds); **Conway,** Arthur, B.Sc. (Eng.), A.C.G.I., G.I.Mech.E. (London); **Conway,** Thomas Patrick (London); **Cook,** Andrew McT. (Sheffield); **Couch,** John Morgan (Cardiff); **Davies,** George Eveleigh (London); **Dean,** Ernest Leslie, A.I.M. (Birmingham); **Driver,** Norman, G.M.I.Mech.E. (Sheffield); **Ebeling,** Dolph G., Ph.D., M.S. (Schenectady, N.Y., U.S.A.); **Edwards,** Geoffrey (Sheffield); **Ellcock,** Douglas William (Cannock); **Emery,** Pierre (Saulnes, France); **Endicott,** George (Worcester, Mass., U.S.A.); **Epron,** Pierre-Marie (Paris); **Fannon,** Robert Leydon (London); **Farmer,** Malcolm Hugh, B.Sc.(Eng.) (Teddington); **Fearnehough,** William (Sheffield); **Fernández,** Ricardo Fernández (La Felguera, Asturias, Spain); **Flubacher,** Franz, Dipl.Ing. (Bedford); **Freeman,** Edward Reykers, M.A. (London); **George,** Wilbert R., B.Sc. (Stafford); **Gibbons,** Kenneth Hugh, B.A. (London); **Goyoaga,** Antonio (Bilbao, Spain); **Graef,** Rudolf, Dr.Ing. (Oberhausen, Germany); **Gray,** Stephen A. R., M.A. (Shotton); **Green,** Clifford Frank, A.M.I. Prod.E. (Birmingham); **Greenhill,** Ernest Stanley (Scunthorpe); **Griffiths-Jones,** K. F. (Brierley Hill); **Hafner,** Mathew (Zenica, Yugoslavia); **Hall,** Eric Skelton, A.Met. (Sheffield); **Harley,** Theodore H., B.C.E. (Dearborn, Mich., U.S.A.); **Hicks,** Harry (Sheffield); **Holland,** Frederick Allen (London); **Howahr,** Erich (Düsseldorf-Rath, Germany); **Howard,** Norman Victor (Sheffield); **Howard,** Thomas George, F.R.I.C. (London); **Hughes,** Hugh Prentice, A.I.M. (Sheffield); **Husson,** L. Gabriel (St. Germain-en-Laye, France); **Hyslop,** Joseph Fraser, D.Sc., A.R.T.C. (Bonnybridge); **Iitaka,** Ichiro, Prof. (Tokyo, Japan); **Inglis,** John Priestley (London); **Ivanso,** E. V. (Detroit, Mich., U.S.A.); **Johansson,** Axel (Finspong, Sweden); **Johnston,** Gilbert Keith, M.A., A.M.I. Mech.E. (Sheffield); **Kelsey,** William Jack (Smethwick); **Kent,** Aubrey E. (Vereeniging, South Africa); **King,** David Edward Charles, B.Sc. (Chingda, Northern Rhodesia); **Kirby,** William Sadler (Sheffield); **Kirkham,** Thomas Howell, B.Sc. (Brierley Hill); **Lauer,** Heber von (Chicago, Ill., U.S.A.); **Leichliter,** Van H., B.S. (Cleveland, Ohio, U.S.A.); **Lerebours-Pigeonnière,** J. (Paris); **Lewis,** John Kenneth (Middlesbrough); **Lomas,** Gerald A.

(Sheffield); **Looveren,** A. M. M. van de, M.Sc. (Amsterdam, Holland); **Lowe,** Joseph Samuel (Preston); **Mavir,** Hartley (Workington); **Meenan,** James G., B.Sc. (Pittsburgh, Pa., U.S.A.); **Milos,** John (Phoenixville, Pa., U.S.A.); **Mirchandani,** Brigadier T. T., M.Sc. Tech., A.M.I.Mech.E. (London); **Mishima,** Tokushichi, Dr.Eng. (Tokyo, Japan); **Morgan,** Francis John (Smethwick); **Morris,** Dorothy Evelyn (Birmingham); **Mukherjee,** Prabhat Charan, B.E.(Met.) (London); **Murakami,** Takejiro, D.Sc. (Sendai, Japan); **Nesland,** Alf (Sauda, Norway); **Orr,** John Patrick Smellie (Dunedin, New Zealand); **Ottar,** Brynjulf (Lilleström, Norway); **Parker,** Thomas Champness (London); **Parkes,** David John Keetch (London); **Pennington,** Cecil Burrows (Cardiff); **Perry,** Timothy Gordon, B.A. (London); **Peters,** Antony T., B.Sc.(Eng.Met.) (Brierley Hill); **Poulten,** Bernard (London); **Powell,** Eric (Jakarta, Indonesia); **Sack,** Rudolf H., Dr.Ing. (Dusseldorf-Rath, Germany); **Sancton,** Edward H., B.Eng. (Hamilton, Ontario, Canada); **Savage,** William Joseph (Seraing, Belgium); **Schenck,** Hermann, Prof.Dr.Ing. (Aachen, Germany); **Schermer,** Kurt, Dipl.Ing. (Frederiksvaerk, Denmark); **Senior,** Roy (Guelph, Ontario, Canada); **Seoudi,** Soad (London); **Sewell,** James Fowler, M.Sc., F.I.M. (Sheffield); **Sharp,** Cyril, A.I.M. (Sheffield); **Smedley,** Ronald James, B.Sc. (Met.) (Wolverhampton); **Srivastava,** K. N., B.Sc.(Met.), A.I.M. (Bochum, Germany); **Storr,** Hardy Eric (Wellingborough); **Sutton,** Henry, M.I.Prod.E. (Birmingham); **Taluja,** Shamsher Singh (Kanpur, India); **Tannery,** Jean Paul (Longwy-Bas, France); **Tarquinee,** Val (The Hague, Holland); **Thomas,** John Harold (London); **Thomas,** Kurt (Düsseldorf, Germany); **Turner,** Wilfred (Brighton); **Udgaard,** Asbjorn (Sauda, Ryfylke, Norway); **Vichit,** Yanyong (Bangkok, Thailand); **Vio,** Rolf, Dr.Ing. (Milan, Italy); **Vizer-Harmer,** Wilfred Thomas (Sheffield); **Wackie-Eysten,** Jan (The Hague, Holland); **Waehlert,** Max., Dr.Ing. (Frankfurt-am-Main, Germany); **Waring,** Frank Leslie, A.M.I.E.E. (London); **Webb,** Henry James, B.Sc., A.M.I.Mech.E. (Bury); **Wild,** Norman, L.I.M., A.M.C.T. (Burton-on-Trent); **Wilkinson,** Henry, B.Sc. (Quebec City, Quebec, Canada); **Williams,** Robert John Llewelyn (Brymbo); **Willis,** Peter B. A., B.Sc., M.Sc., A.I.M. (Cardiff); **Winkel,** Erik Caprani, M.Sc. (Frederiksvaerk, Denmark); **Young,** Peter Alexander, M.A. (Cambridge); **Yukawa,** Masao (Yawata, Japan); **Yum,** Yung-ha, Bc.Mech. (Seoul, Korea); **Zacca,** L. Y. (Beyrouth, Lebanon).

Associate Members

Bailey, Norman John (Newcastle-on-Tyne); **Banks,** Peter (Stamford); **Barton,** James Wilson (Liverpool); **Bowden,** Alan Dennis (Bilston); **Carrier,** Arthur George Elliston (London); **Davey,** Henry Brian (Erith); **Duley,** Derek William (Bilston); **Godwin,** Roy Sidney (Birmingham); **Greenhill,** John Malcolm (Coventry); **Kilburn,** M. (London); **King,** Arthur David Newton, B.A. (Birmingham); **Lahiri,** Amiya Kumar, B.Sc.(Met.Eng.) (Banaras, India); **Lang,** Hugh M., B.Sc., A.R.T.C. (Glasgow); **Madhekar,** Mukund Keshav, B.E.(Met.) (Manchester); **Major,** Brian (Scunthorpe); **Mason,** Robert, jun. (Newcastle-on-Tyne); **Mitchell,** Andrew Baird (Liverpool); **Morgan,** Gomer Wynne (Swansea); **Morgan,** Hywel Lynne (Ammanford); **Morris,** Derek (London); **Petty,** Evan Robert (Swansea); **Plastow,** Byron (Scunthorpe); **Prabhu,** Bantval Vishwanatha (Banaras, India); **Purdie,** John, A.Met. (Rotherham); **Richards,** P.O. Walter Graham (R.A.F.); **Roderick,** David Thomas Benjamin Peter (Swansea); **Smith,** Thomas Barry, B.Sc. (Birmingham); **Stringer,** John (Liverpool); **Szajda,** Thaddaeus Jaroslaus (Swansea); **Turner,** Brian Foster, B.Sc.(Hons.Met.) (Cardiff); **Wallwork,** Alfred (Bilston); **Young,** John James (London).

The **Chairman** declared these candidates to be duly elected. They numbered 158, bringing the total Membership of the Institute to 4931. That was the highest figure that the Membership of the Institute had reached; they were now within a very short distance of achieving the aim of a Membership of at least 5000.

PRESENTATION OF PAPERS

Papers presented and discussed at the Autumn General Meeting were as follows (dates of publication in the *Journal* are given in parentheses):

Tuesday, 24th November, 1953

Afternoon Session

Joint Discussion on:

"The Effect of Emissivity and Flame Length on Heat Transfer in the Open-Hearth Furnace," by M. W. Thring (*August*, 1952).

"Experiments on Flame Radiation in an Empty Open-Hearth Furnace," by W. P. Cashmore and M. W. Thring (*October*, 1953).

"The Length of Oil and Gas Flames," by A. L. Cude (*November*, 1953).

Discussion on:

"The Water-Cooling of Open-Hearth Furnaces," by A. M. Frankau (*May*, 1953).

Wednesday, 25th November, 1953

Morning Session

Joint Discussion on:

"The Notched Slow-Bend Test as a Brittle-Fracture Test," by J. E. de Graaf and J. H. van der Veen (*January*, 1953).

"The Fracture of Alpha Iron," by C. F. Tipper and E. O. Hall (*September*, 1953).

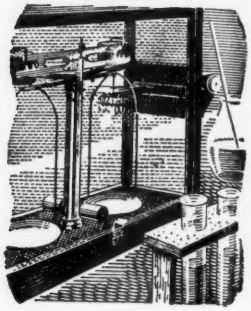
"Intergranular Brittleness in Iron–Oxygen Alloys," by W. P. Rees and B. E. Hopkins (*December*, 1952).

"The Cleavage Strength of Polycrystals," by N. J. Petch (*May*, 1953).

Discussion on:

"Tensile and Impact Properties of High-Purity Iron–Carbon and Iron–Carbon–Manganese Alloys of Low Carbon Content," by N. P. Allen, W. P. Rees, B. E. Hopkins, and H. R. Tipler (*June*, 1953).

The papers presented at the Symposium on Sinter and the discussion are to be published in one volume in the Special Report Series.



A Carbon-Resistance Furnace

FOR THE DETERMINATION OF GASES IN STEEL BY THE VACUUM-FUSION METHOD

By R. M. Cook, B.Sc.(Eng.), and G. E. Speight, B.Sc., F.R.I.C., F.I.M.

SYNOPSIS

A vacuum-fusion apparatus, incorporating a carbon-resistance furnace, for the determination of gases in steel is described. The furnace, which is of robust construction, employs a split graphite heating element situated within a water-cooled stainless-steel tube. Power is supplied directly from the mains through a small step-down transformer, thereby obviating the need for a costly high-frequency generator. The apparatus includes a new form of analytical system for the rapid determination of oxygen and nitrogen contents, although provision is made also for the analysis of the extracted gases by conventional methods. The advantages of the apparatus are briefly discussed. 861

THE determination of oxygen, hydrogen, and nitrogen in steel by the vacuum-fusion method, employing a H.F. furnace, has been described many times during the past twenty years. This method of heating undoubtedly possesses advantages over the carbon-spiral method, such as the very high degassing temperatures which, together with the relatively simple furnace construction, yield extremely low blank values under ideal working conditions.[1] A serious disadvantage of H.F. heating, however, is that a relatively elaborate generator is necessary, and this is a costly item.

The vacuum-fusion apparatus described in this paper has two main features:

(*a*) An improved design of carbon-resistance furnace which operates from the normal mains supply through a small step-down transformer

(*b*) A simplified analytical system to provide for the analysis of oxygen and nitrogen *in situ*, thereby effecting a considerable saving in time.

Initially attempts were made to provide a satisfactory carbon-spiral furnace, but the relatively large amounts of graphite required gave high blank values and necessitated long degassing times. There was also a tendency for electrical discharge to occur within the furnace at the required voltages.

Thanheiser[2] designed a furnace consisting of two concentric graphite tubes as heating elements fitted into a water-cooled silica furnace tube, thereby reducing the amount of graphite required. Electrical discharge within the furnace was eliminated because a low voltage was used, but the current requirements were relatively high. Special precautions were also necessary to prevent leakage of gas at the metal-to-silica joints.

The furnace described in this paper is a modification of that designed by Thanheiser; it uses a split cylindrical graphite heating element, and considerable saving in power is effected by the use of a graphite radiation shield. A water-cooled stainless-steel furnace tube eliminates the danger of breakage or of leakage due to differential expansion.

VACUUM-FUSION APPARATUS

Furnace

The graphite crucible assembly (Figs. 1 and 2) consists of the heating element, radiation shield, and melting crucible; it is supported on the base flange by means of two copper conductors. The cylindrical graphite heating element is bolted tightly to the two copper conductors and is split longitudinally from the bottom to a point $\frac{1}{2}$ in. from the top, thus forming a resistive path for the current between the conductors. This method of mounting ensures good electrical contact between the graphite and the copper, and eliminates trouble due to expansion of the graphite on heating and cooling. The water-cooled conductors, which are chromium-plated to minimize gas adsorption within the furnace, are secured to the stainless-steel base flange by insulated vacuum-tight seals.

The radiation shield consists of two concentric thin-walled graphite tubes, the annular space between them being filled with 300-mesh graphite powder. This method of screening, which is commonly used with the H.F. furnace, is even more effective with the type of furnace used in this work, as inductive heating of the radiation shield is entirely absent.

Paper SM/BB/58/53 of the Gases and Non-Metallics Sub-Committee of the Steelmaking Division of the British Iron and Steel Research Association, received 30th July, 1953. The views expressed are the authors', and are not necessarily endorsed by the Sub-Committee as a body.

Mr. Cook is Research Chemist and Mr. Speight is Chief Chemist at the United Steel Companies, Ltd., Research and Development Department, Rotherham.

The melting crucible, which is designed to accommodate up to eight 15-g. samples, is suspended inside the heating element with an annular gap of $\frac{1}{32}$ in., to prevent an electrical short-circuit. A graphite cone and stopper closes the mouth of the crucible and prevents undue splashing with high-oxygen steels.

The furnace chamber (Fig. 2) consists of a stainless-steel tube, 3 in. dia. and 15 in. long, cooled by a copper coil soldered to the outside. Gases are extracted through a short wide-bore side-arm connected to the diffusion pump by a large metal tap. The latter serves to maintain the pump under vacuum when the furnace is recharged. Measurements of furnace pressure are made by a standard McLeod gauge connected to the furnace tube through a side-arm located above the crucible. A glass head, provided with sight window and two sample arms, is connected to the furnace tube through a cone-and-socket joint, which is water-cooled to obviate trouble due to differential expansion. The lower end of the furnace tube terminates in a stainless-steel flange, to which is bolted the base flange of the crucible assembly. A vacuum-tight joint is ensured by the use of a greased rubber ring fitting into a groove in the base flange.

Power Supply—Current is supplied to the two conductors through 250-amp. flexible cables connected through an ammeter to the secondary winding of a small step-down transformer. The primary winding is connected to the 240-V. single-phase supply, the primary voltage being controlled by means of a variable resistance. Power requirements are:

Degassing (2100° C.) : 16 V., 250 amp. (4 kVA.)
Melting (1650° C.) : 13 V., 200 amp. (2·6 kVA.)

Gas Extraction—Gases are extracted from the furnace by means of a 2-stage mercury diffusion pump with a speed of 20 l./sec. at 10^{-3} mm. of Hg and a maximum backing pressure of 2–3 mm. of Hg. Although this low backing pressure is adequate for most samples, extraction times are somewhat prolonged with the higher gas contents. In this respect a 3- or 4-stage pump would be preferable. The outlet from the diffusion pump is connected to the analytical system by a 3-way tap, to allow for the removal of gases by the rotary oil pump during the degassing period.

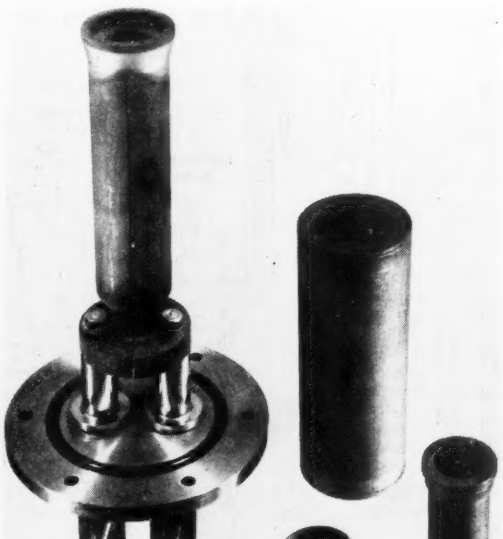


Fig. 1—Graphite crucible assembly

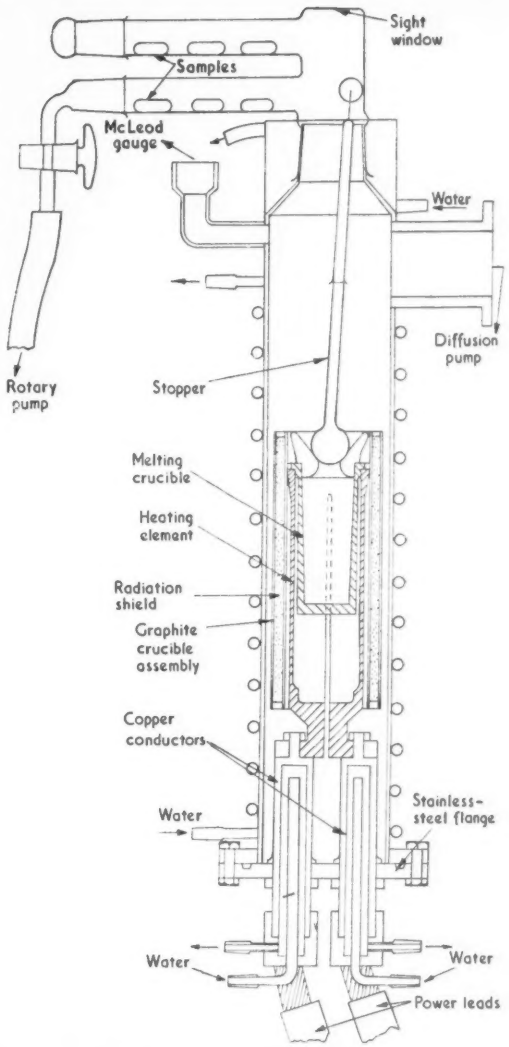


Fig. 2—Vacuum-fusion furnace

Analytical System

During the melting of samples the gas evolved, consisting of carbon monoxide, hydrogen, and nitrogen, is delivered to the analytical system (Fig. 3). Carbon monoxide and hydrogen are oxidized completely to carbon dioxide and water, respectively, by means of a copper oxide catalyst maintained at 600° C.; the water is retained in a phosphorus pentoxide trap. The residual gas, which at this stage

consists entirely of carbon dioxide and nitrogen, is collected in the calibrated bulbs by means of a single-stage mercury diffusion pump of high backing pressure, followed by a combined Toepler pump and McLeod gauge.

The pressure of extracted gas is measured at constant volume. The calibrated bulbs provide three known volumes measured from tap *T*7, *i.e.*, including the freezing trap; all pressure measurements are taken with the latter at room temperature. The actual volumes are 6·685, 13·88, and 30·15 ml.; 1 mm. measured pressure difference of CO_2 is equivalent to 0·00005, 0·0001, and 0·00025% oxygen, respectively, on the basis of a 15-g. sample. A total gas content of 18 ml. at N.T.P. may be measured, which has proved adequate for most steel samples. For higher gas contents, the sample weights are reduced accordingly.

The freezing trap provides for the separation of the carbon dioxide and nitrogen; the oxygen and nitrogen contents of the sample may be calculated from the difference of the total gas pressure and the pressure of carbon dioxide alone. Normally, no attempt is made to measure the hydrogen content with this system, as hydrogen analyses are carried out more conveniently by the low-temperature extraction method. Provision is made, however, for collection of the entire gas sample, *via* a separate Toepler pump, in special cases where the contents of all three gases are required.

Catalyst

The accuracy of this method of analysis is largely dependent upon the activity of the copper oxide catalyst, since unoxidized carbon monoxide and hydrogen would be recorded as nitrogen. Early tests with various forms of superficially oxidized copper were not entirely successful, as complete oxidation was only obtained by passing the gas over the catalyst a number of times.

Granular copper oxide proved to be more reactive, and eventually the Arneil catalyst described by Gooderham[3] was adopted. This was prepared by thoroughly mixing finely ground pure CuO, Fe_2O_3, and kaolin in the proportions 99 : 1 : 20. Water was added and the resultant paste was formed into threads by squeezing it through a 2-mm. dia. orifice. After drying, the threads were broken into suitable lengths, fired at 600° C., and packed loosely into a fused silica **U**-tube. Before use, the catalyst was completely reduced in a stream of hydrogen and reoxidized at 600° C. Tests carried out with synthetic gas samples showed that complete oxidation of carbon monoxide and hydrogen could be achieved with volumes of gas far greater than those normally encountered in vacuum-fusion tests. Recirculation of the gas over the catalyst was therefore unnecessary.

The catalyst is regenerated periodically by heating at 600° C. in a stream of oxygen.

ANALYTICAL PROCEDURE

Blank Determination

The furnace is assembled and the sample arms are charged with the required number of degreased and weighed samples. Preliminary evacuation is carried out by the rotary oil pump through tap *T*1, and finally by means of the diffusion pump with *T*1 closed, *T*2 open, and *T*3 and *T*8 open to the rotary oil pump. When a pressure of 10^{-4} mm. of Hg or less is registered, the furnace is switched on and the temperature is raised gradually to 2100° C., temperatures

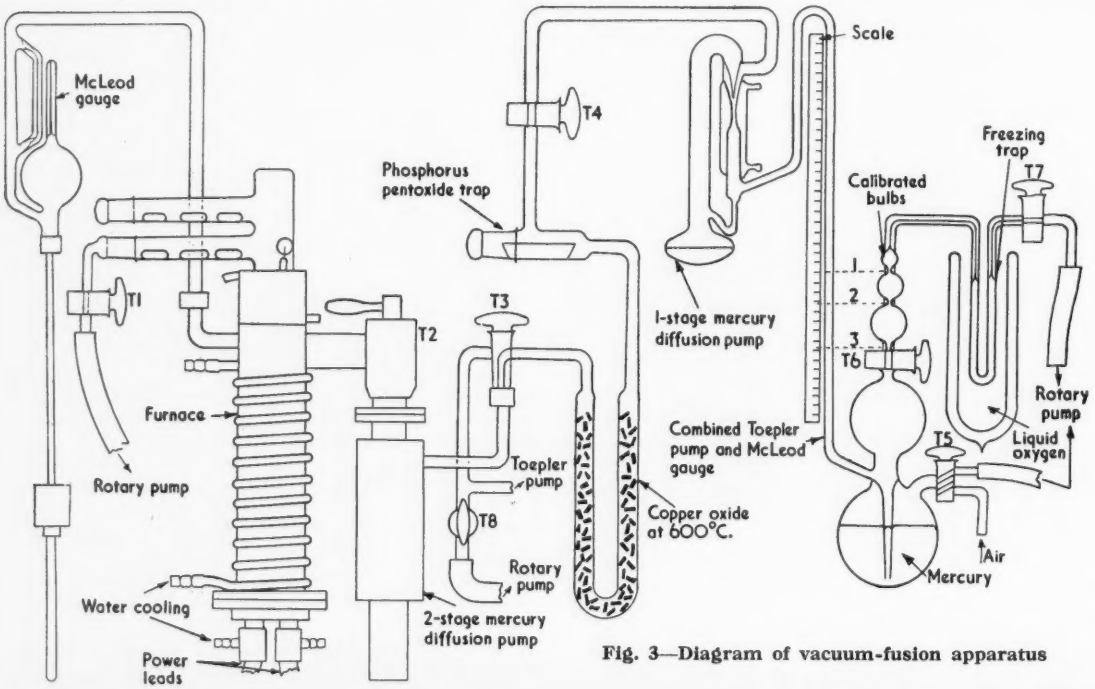


Fig. 3—Diagram of vacuum-fusion apparatus

being measured with an optical pyrometer located above the sight window. The graphite crucible assembly is degassed at this temperature until a pressure of 5×10^{-5} mm. of Hg or less is indicated; the furnace temperature is then lowered to 1650° C. in readiness for the blank determination. The total degassing time required to attain this base pressure is 2–3 hr. and, to enable the maximum number of determinations to be carried out, the furnace has usually been operated at 2100° C. for 2 hr. on the previous day. The base pressure may then be attained after ½–1 hr. at this temperature. During the degassing period, the analytical system is evacuated by means of the rotary oil pump, with taps *T*4, *T*6, and *T*7 open.

When a steady furnace temperature of 1650° C. is indicated, with a base pressure of the order of 10^{-5} mm. of Hg, *T*3 is opened to the analytical system and *T*7 closed for the collection of the blank sample. The Toepler pump is operated periodically by the manipulation of *T*5 and at each stroke *T*6 is closed, to retain the gas sample in the calibrated bulbs. After 5 min. the mercury is taken up to the calibrated position 1 and the pressure difference noted. This procedure is repeated at 5-min. intervals until a constant rate of pressure increase is attained. After 30 min. a final pressure reading is taken, and liquid oxygen is placed round the freezing trap. Tap *T*7 is then opened to remove the residual nitrogen and the carbon dioxide remains in the freezing trap. After ½ min., *T*7 is closed, the liquid oxygen removed from the freezing trap, and the latter warmed to room temperature by a stream of hot air. The mercury level is then readjusted to the calibrated position 1 and the pressure difference due to the carbon dioxide is noted. Thus, by subtraction, the volume of nitrogen may be calculated. The gas is removed by opening *T*7 to the rotary oil pump, and the mercury is taken down in readiness for the first sample.

Vacuum-Fusion Analysis of Samples

After the power has been switched off, the first sample is dropped into the furnace and the stopper is raised to allow it to fall into the crucible. The power is switched on and, as soon as the sample melts, the Toepler pump is operated to collect the gas sample as described for the blank determination.

During the first 5–10 min. it is necessary to pump continuously owing to the low backing pressure of the diffusion pump. Periodic readings of furnace pressure are taken on the McLeod gauge until the base pressure is nearly attained. The gas sample collected is then measured at the smallest possible calibrated volume. Readings are taken at 5-min. intervals until the rate of increase is the same as that obtained with the blank determination. After the final reading, the mercury is lowered until the level in the measuring limb is below the top of the calibrated bulbs, to prevent mercury from entering the freezing trap when the nitrogen is removed. Liquid oxygen is then placed on the freezing trap and *T*7 is slowly opened to remove the nitrogen. After ½ min. *T*7 is closed, the liquid oxygen removed, and the freezing trap warmed to room temperature. The pressure of carbon dioxide is then measured at the same calibrated volume; by subtraction from the total gas pressure, the pressure due to nitrogen alone is obtained. At this stage the power is usually switched off, to allow the crucible to cool 100–200° C. before the next sample is introduced; this prevents undue splashing of the melt in the case of high gas contents.

The carbon dioxide is finally removed from the system through *T*7, the mercury is taken down, and the next sample is extracted in the same way; subsequent samples are analysed by the same procedure.

Although the crucible temperature remains very constant for a given power input throughout the melt, temperature readings are taken for each sample and adjustments are made when necessary to compensate for mains variations. With the exception of aluminium-bearing steels, which are melted at 1750° C., all tests are carried out at 1650° C.

Procedure for the Determination of Oxygen

In many cases, only the oxygen content of the sample is required and a simplified procedure may be adopted.

Liquid oxygen is first placed round the freezing trap and *T*7 is opened to the rotary oil pump. The sample is introduced and, as the gas is evolved, the nitrogen is continuously removed from the analytical system by means of the rotary oil pump, the carbon dioxide being retained by the freezing trap. When the base pressure is attained in the furnace, *T*4 is closed and the mercury is raised to calibrated position 1 to ensure complete removal of nitrogen from the bulbs. Tap *T*7 is closed and the liquid oxygen removed; the freezing trap is warmed to room temperature and the pressure of carbon dioxide measured. The latter is pumped out by opening *T*7, the liquid oxygen is replaced on the freezing trap, and the mercury is taken down. Tap *T*4 is opened and the carbon dioxide collected and measured as described for a further 5 min., to ascertain whether the extraction is complete. This additional step is unnecessary if the test is continued for 5 or 10 min. after the base pressure is reached.

RESULTS

The following example illustrates the method of calculation of the oxygen and nitrogen contents of a sample.

Weight of sample = 15·61 g.

Pressures p of gas measured at calibrated position 2 (13·88 ml.):

For $CO_2 + N_2$ $p = 318$ mm.
and for CO_2 $p = 189$ mm.
$\therefore$ for N_2 $p = 129$ mm.

Temperature = 22° C.

Volume of CO_2 at N.T.P.

$$= \frac{189}{760} \times 13{\cdot}88 \times \frac{273}{295} = 3{\cdot}20 \text{ ml.}$$

Volume of N_2 at N.T.P.

$$= \frac{129}{760} \times 13{\cdot}88 \times \frac{273}{295} = 2{\cdot}18 \text{ ml.}$$

After blank corrections:

Volume of CO_2 at N.T.P. = 3·14 ml.
„ „ N_2 „ „ = 2·16 ml.

Table I

RESULTS OBTAINED WITH THE CARBON-RESISTANCE AND H.F. FURNACES

Sample	Type of Steel	Carbon-Resistance Furnace		H.F. Furnace	
		Oxygen, %	Nitrogen, %	Oxygen, %	Nitrogen, %
J.5926	Plain carbon, basic electric-arc	0·004 0·004$_5$ 0·003$_5$	0·005$_5$ 0·005$_5$ 0·006$_5$	0·003$_5$ 0·004 0·003$_5$	0·006$_5$ 0·006$_5$ 0·005$_5$
4654	Low-carbon, basic Bessemer, Al-killed	0·004 0·004$_5$ 0·004$_5$	0·008 0·008 0·008$_5$	0·004 0·004 0·004$_5$	0·007$_5$ 0·008 0·007$_5$
8652	Low-carbon, basic Bessemer	0·014 0·014$_5$ 0·014$_5$	0·018 0·017$_5$ 0·018	0·014 0·014$_5$ 0·015$_5$	0·017 0·016 0·016
784	Al-killed, basic O.H.	0·010	0·004	0·009$_5$	0·004$_5$
2B	Al-killed, furnace sample	0·073	0·002$_5$	0·074	0·003
V4	0·44% V, H.F.	0·013	0·016	0·012$_5$	0·017$_5$
X.598	3% Ni, H.F.	0·026	0·007	0·026	0·005
H.624	4¾% Ni, basic electric-arc	0·005$_5$	0·007$_5$	0·005$_5$	0·007$_5$

$$\text{Therefore, oxygen content} = \frac{3\cdot14}{15\cdot61} \times \frac{16 \times 100}{22{,}400} = 0\cdot0145\%$$

$$\text{and nitrogen content} = \frac{2\cdot16}{15\cdot61} \times \frac{28 \times 100}{22{,}400} = 0\cdot0175\%.$$

Typical results obtained on a number of steels using the carbon-resistance furnace are given in Table I. For comparison, results obtained with the former apparatus, using the H.F. furnace, are included. Triplicate results for three reference steels are also given, to show the degree of reproducibility obtained with the carbon-resistance furnace.

DISCUSSION

Examination of the results shows good agreement between the gas analyses obtained with the carbon-resistance and H.F. furnaces, and reproducibility is satisfactory in each case.

The total blank obtained with the carbon-resistance furnace is of the order of 0·1 ml. per 30-min. period, the average composition being carbon dioxide 70%, nitrogen 30%. Although this blank is slightly higher than that obtained with the former H.F. furnace, it increases only slightly throughout the melt. This value includes the blank due to the analytical system, *i.e.*, the gas evolved by the CuO catalyst, so that the total error is probably less significant than in the conventional method of gas analysis used in conjunction with the H.F. furnace.

The time cycle is 25–35 min. per sample with an additional 2–3 min. for the separation and measurement of carbon dioxide and nitrogen. The provision of a more efficient diffusion pump, however, would considerably reduce these times, and under optimum working conditions it would be possible to obtain results for oxygen and nitrogen in 20–25 min.

CONCLUSIONS

The apparatus has been in operation for a considerable time and has furnished consistent results over a large number of determinations. The following advantages over the former apparatus have been observed:

(1) The simpler furnace construction enables reassembly to be carried out in a shorter time than was possible with the H.F. furnace.

(2) With this method of heating, the crucible temperature remains very steady for a particular power input; thus it is possible to dispense with temperature measurements, and to rely solely on the ammeter readings.

(3) The quantity of metal vapour condensed on the inner wall of the furnace is considerably less than that occurring with the H.F. furnace; it is therefore unnecessary to melt with tin in the case of aluminium and manganese steels.

(4) This method of gas analysis effects a considerable saving in time over the conventional methods, so that more tests can be carried out each week.

Acknowledgments

The authors' thanks are due to the Directors of the United Steel Companies, Ltd., for permission to publish this work, and to the Director of Research and Development, Mr. F. H. Saniter, and the Research Manager, Mr. W. E. Bardgett, for their personal interest and encouragement.

References

1. H. A. Sloman: 7th Report on the Heterogeneity of Steel Ingots, Spec. Rep. No. 16, pp. 82–100: 1937, London, The Iron and Steel Institute.
2. G. Thanheiser and E. Brauns: *Arch. Eisenhüttenwesen*, 1935–36, vol. 9, pp. 435–439.
3. W. J. Gooderham: *J. Soc. Chem. Ind.*, 1938, vol. 57, p. 391.

Determination of Oxygen, Hydrogen, and Nitrogen in Cast Iron

By B. B. Bach, B.Sc., A.R.I.C., J. V. Dawson, and L. W. L. Smith, B.Sc.

SYNOPSIS

A vacuum-fusion apparatus incorporating some novel features and suitable for the determination of oxygen, hydrogen, and nitrogen in cast iron is described. Details of the method of operation and precautions necessary to obtain low blanks and accurate results are given. The need for a special sampling technique is shown and a suitable sampling method for oxygen and nitrogen is described. The reproducibility of the whole method, including sampling, is also given. 857

For a long time it has been suggested that gases affect the properties of cast iron and cause defects. To investigate these effects it was necessary to be able to determine the gas content. It was already known that the only gaseous elements present were oxygen, hydrogen, and nitrogen.[1, 2, 3] A survey of the literature showed that the most promising method was that of vacuum-fusion in a graphite crucible. Accordingly, a carbon spiral resistance furnace based on the design of Newell[4] was constructed and a number of samples were analysed. It soon became apparent, however, that the results obtained were not reliable, owing to the presence of a high 'blank.' This was especially so in the case of nodular cast irons, where the oxygen content is very low. Attempts to reduce the 'blank' by using longer degassing times or higher temperatures were unsuccessful, and so it was decided to install a high-frequency furnace.

VACUUM-FUSION APPARATUS

The basic design used for the induction-heated apparatus was that of Sloman.[3] Certain modifications were made, however, and only these are described in detail.* The apparatus, shown in Fig. 1, consists of a transparent fused-silica tube *A* connected by a *B*.60 ground joint to a transparent silica head *B*, to which is sealed an optical window *C*. A 25-mm. Pyrex glass stopcock *S*1 is used for isolating the furnace tube from the diffusion pump. This stopcock is connected to the diffusion pump by a stainless-steel extension tube *F* sealed to the pump by an O-ring gasket. The outlet of the pump is joined *via* two modified diaphragm valves *S*2 and *S*4 to a Toepler pump *P*. Induction heating is applied to the furnace by means of coil *O*, which is immersed in the Perspex water jacket *Q*. A graphite crucible assembly *T* (*see* Fig. 2) is supported inside the silica tube by means of the appendix and is surrounded by graphite powder (−200 mesh).

Details of certain parts of the apparatus which have important or unusual features are as follows:

Silica Furnace Tube (*A*)—It is important to specify that the appendix tube does not narrow where it joins the main tube. Considerable trouble was experienced in the early stages from hot spots occurring at this point, with subsequent cracking of the tube.

Glass Sample Tube (*E*)—This has an *A*.34 cone which fits into a *B*.34 socket. This obviates the danger of grease from the joint contaminating the samples.

Toepler Pump (*P*)—The total volume of the pump is about 800 ml. It is fitted with a ball valve to prevent mercury from passing into the diffusion pump. The method of operation is as follows:

> Open stopcock *S*8 to the atmosphere, thus compressing the gas into the small bulb; turn stopcock *S*10 through 180° to connect the small bulb to the reservoir and open stopcock *S*7; the gas then passes up into the storage tube. A graduated scale is fitted to the vertical tube so that small volumes of gas, such as from the 'blank,' can be measured directly. Stopcock *S*9 is used for draining off excess mercury.

Graphite Crucible Assembly (*T*)—This is shown in detail in Fig. 2. It is easier to construct than the design used by Sloman.[5] Considerable trouble was experienced at first from the funnel working loose and being lifted with the stopper. This difficulty has been completely overcome by the use of pins, as shown in Fig. 2. Another difficulty that occasionally arose was that the samples sometimes broke the stopper off the rod. This was obviated by the use of a thin tungsten strengthener in the rod. The angle of the funnel was also found to be critical: too steep an angle caused the stopper to stick and too shallow an angle caused the samples to stick in the funnel.

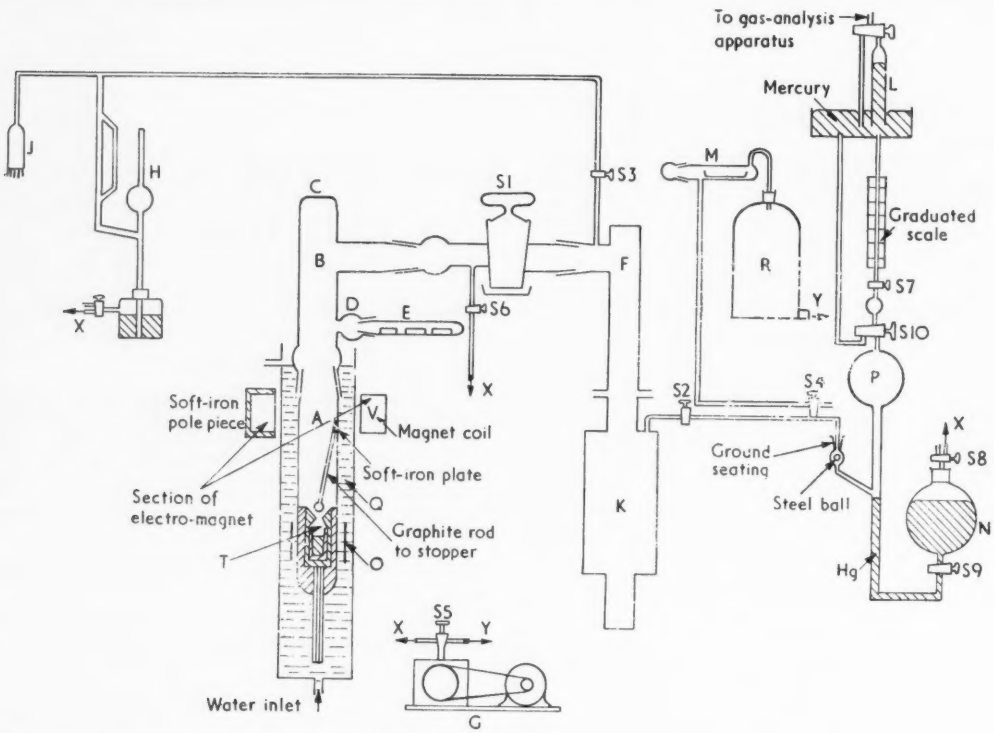
Magnet Coil (*V*)—A short solenoid fitted with a decentralizing soft-iron pole covering about 60° of the circumference is used to lift the stopper. A curved soft-iron sheet about 1½ in. square is attached to the stopper rod in place of the more usual soft-iron tube. This was found to give considerably more lift. A synchronous rotary switch energizes the magnet coil every 15 sec. to prevent graphite vapour from welding the ball to the funnel.

High-Frequency Generator and Work Coil—A 30-kW. valve oscillator operating at 400 kilocycles/sec.

* A more detailed description is available on application to the British Cast Iron Research Association.

Manuscript received 12th May, 1953.

Mr. Bach, Mr. Dawson, and Mr. Smith are with the British Cast Iron Research Association.



A. Silica furnace tube
B. Silica head
C. Optical window
D. *B*.34 socket
E. Glass sample tube
F. Stainless-steel extension tube
G. Two-stage rotary oil pump
H. McLeod gauge (0·1–0·00001 mm. of Hg)
J. Pirani gauge
K. Four-stage metal mercury-diffusion pump (backing pressure 25 mm. of Hg)
L. Gas sample tube
M. Drying trap
N. Toepler reservoir
O. Work coil
P. Toepler pump
Q. Perspex water-cooling jacket
R. Reservoir (6-l. capacity)
S. Stopcocks or valves
T. Graphite crucible assembly
V. Magnet coil

Fig. 1—Pumping system

is used to supply power to the crucible. It is controlled by a moving-coil regulator which gives smooth stepless control over a wide range. During the initial experiments trouble was experienced with a glow discharge which occurred when the pressure in the silica tube rose as a result of gas evolution. When this occurred, gas adsorbed on the glass ware was evolved, causing erroneous results. This effect was eventually traced to a combination of the relatively high frequency used and the high voltage (1000 V. or more) across the work coil. A stepdown transformer (concentrator) was therefore fitted between the generator and the work coil so that the voltage was reduced to about 100 V. This entirely eliminated the glow discharge. It had the additional advantages of safety and of allowing the coil to be immersed directly in the cooling water, thus ensuring closer coupling between the coil and the crucible. The coil is constructed from copper sheet bent into the shape of a tube and cemented into a piece of asbestos-based plastic sheet by means of a thermo-setting plastic cement. The plastic sheet is then fitted to the Perspex water tube by means of a rubber O-ring gasket.

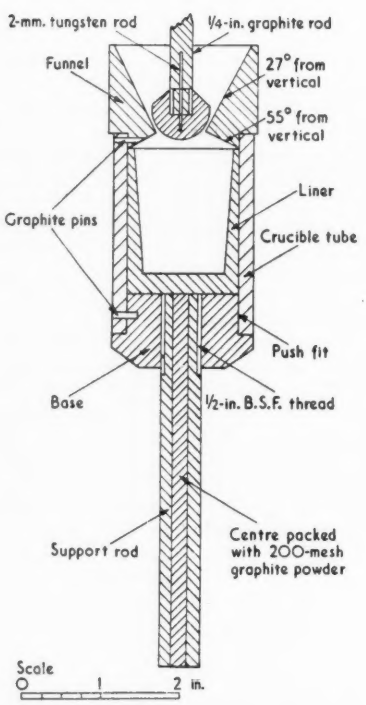


Fig. 2—Graphite crucible assembly

A total of 9 kW. is required to heat the crucible to 2400° C. and 5 kW. is needed for the operating temperature (1650° C.). Both these figures include 3 kW. used for the valve heaters, fans, etc.

Gas Analysis—A modification of the Ambler gas-analysis apparatus is used (*see* Fig. 3). This is a constant-volume apparatus using mercury as the confining liquid. Three-way 120° stopcocks are used, as these have proved to be more reliable than the conventional type. The manometer is unusual in that it can be used either open or closed. When used closed a few drops of 1% nitric acid are placed in the top to prevent fouling of the mercury and to compensate for the water-vapour pressure.

The procedure adopted for analysing the gas is briefly as follows:

The gas is compressed into a suitable volume and the pressure is measured. Carbon monoxide is then absorbed with two quantities (about 0·5–1·0 ml.) of ammoniacal cuprous chloride. A low cupric-salt content is essential. This is obtained by preparing and storing the reagent in an inert atmosphere.[9] The apparatus is then washed with water followed by 1% nitric acid (the gas is not washed, *i.e.*, it does not come into contact with large volumes of liquid to prevent loss due to solubility), and the pressure is again measured. The gas is then mixed with about an equal volume of oxygen, the pressure is again measured, and the hydrogen is burned on the platinum/10% rhodium spiral. To eliminate grease from the spiral it is first heated in air before transferring the gas. Nitrogen is determined by difference. Oxygen, carbon dioxide, and methane are not determined, as experience has shown that these are never present in sufficient quantities to cause error. A complete analysis takes about 10–15 min.

VACUUM-FUSION PROCEDURE

All samples used are machined to size in a 3½-in. heavy-duty lathe. As smooth a surface as possible is obtained by the use of a fine feed and sharp tools. This can readily be obtained, even on chill-cast material, by using 200 r.p.m. and 0·0037-in. feed. After machining, the samples are only handled with clean tongs. The usual size is about 1 in. long × ½ in. dia., with rounded ends, weighing about 20 g. Smaller samples can, of course, be used if the gas content is too high. After machining, the samples are degreased in the vapour of boiling carbon tetrachloride, weighed, and immediately placed in the sample tube.

To set up the apparatus the silica tube is placed in a special rubber-covered stand and the crucible assembly and guide are inserted. Graphite powder (−200 mesh) is then poured in and consolidated up to the bottom of the crucible by bouncing on the rubber pad. Around the sides of the crucible the powder is poured in loosely and not consolidated. This is to reduce the loss of electrical power in the powder. The guide is then removed, the powder is

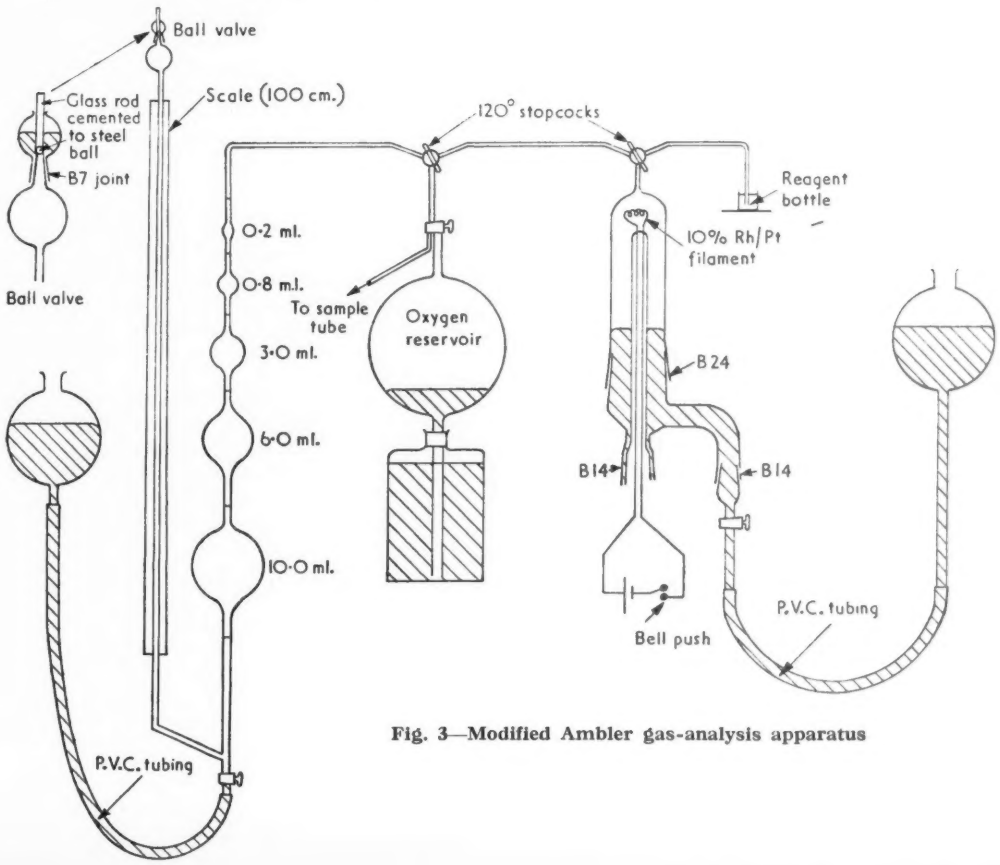


Fig. 3—Modified Ambler gas-analysis apparatus

Table I

EFFECT OF POROSITY ON OXYGEN, HYDROGEN, AND NITROGEN CONTENTS OF GREY CAST IRON

Metal cast in form of slabs 12 in. × 6 in. × 1 in. All results in wt.-% × 10^4

Ref. No.		Edge (Sound)	Centre (Porous)
R.1	Oxygen	18	410
	Hydrogen	1·3	10·4
	Nitrogen	36	35
R.2	Oxygen	20	93
	Hydrogen	1·3	2·0
	Nitrogen	40	42

blown out of the crucible, and the stopper is inserted. The cone on the tube is then greased with hard rubber grease (vacuum grade) and inserted into the socket on the head. It is held in position by two strings looped around the appendix tube and fastened to springs on the framework. The Perspex tube is then slipped on, clamped, and filled with water. The sample tube, which is also greased with hard rubber grease, is placed in the side socket. The furnace is then pumped down very slowly through stopcock *S*6. Care has to be taken at this stage to prevent graphite powder being blown out of the tube by entrapped air. When evacuation is complete, stopcock *S*6 is closed and the system is left overnight. The next morning, stopcock *S*1 is opened and the whole apparatus is evacuated with the mercury pump and backing pump operating.

When evacuation is complete, the power is turned on to the coil and the crucible is gradually heated to 2400° C. Temperatures are measured by means of a disappearing-filament optical pyrometer. The ball is operated every 15 sec. after the temperature reaches 2000° C. The furnace is degassed for 3 hr. at 2400° C., when the McLeod pressure should be about 10^{-4} mm. of Hg or less. The temperature is dropped to 1650° C. and valve *S*4 is closed. The Toepler pump is stroked two or three times to remove adsorbed gas and the blank evolution over a period of 1 hr. is determined. The volume of gas can be estimated from the scale as already described.

If the blank volume is satisfactory (a suitable value is less than 0·02 ml. total gas per hour), the ball is lifted and the first specimen is dropped into the furnace by means of a magnet, the ball being immediately replaced to prevent splashing and to reduce film formation. The gas is collected in the Toepler pump and removed after 15 min. (earlier if the volume of gas is large). Collection is continued until evolution is complete; this is indicated by no gas being collected over a 5-min. period. The process is repeated for 6 or 8 samples. Occasionally, especially with samples containing much nitrogen, evolution is slow and may take up to 45 min. for completion; usually, however, 20 min. suffices. This rather slow evolution is believed to be due to lack of stirring caused by the use of a higher frequency than usual.

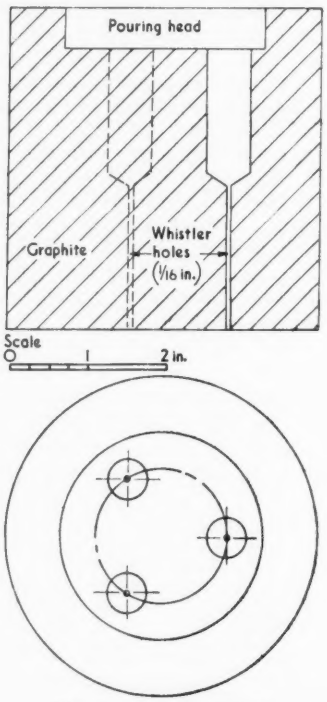


Fig. 4—Sample mould

To keep the blank evolution down to the required value certain precautions have been found necessary. Utmost cleanliness is, of course, essential. Other precautions are to keep the diffusion pump evacuated at all times by closing stopcock *S*1 before releasing the vacuum, and to seal all stopcocks top and bottom with grease, small glass cups being fitted to the bottom to hold the grease.

The graphite powder (prepared by filing as recommended by Sloman[5]) and the crucible assembly are washed before use by boiling in strong hydrochloric acid, followed by thorough washing with water. They are then dried by heating to dull-red heat. This treatment is repeated occasionally if the ' blank ' shows

Table II

EFFECT OF STORAGE ON GAS CONTENTS OF SAND-CAST GREY IRONS

Samples stored for 6–7 weeks in open air and vacuum desiccator. All results in wt.-% × 10^4

Ref. No.	Original Material			Air-Stored			Vacuum-Stored			Composition, %					
	O	H	N	O	H	N	O	H	N	Total C	Si	P	Mn	S	Mg
R.1	18	1·3	36	23	1·2	34	19	1·3	39	3·5	2·0	0·5	0·7	0·16	...
R.2	20	1·3	40	21	1·3	43	19	1·3	44	3·5	2·0	0·5	0·7	0·16	...
G.2*D**	2·5	2·2	40	2·0	2·0	37	...	...	...	2·9	2·3	0·05	0·5	0·02	0·03
G.9*B*	17	1·2	41	16	0·9	47	...	...	...	3·3	1·4	0·06	0·5	0·13	...

* Nodular structure

Table III

COMPARISON OF OXYGEN CONTENT OF VARIOUS TYPES OF CHILL SAMPLE

All results in wt.-% × 10^4

Ref. No.	Open Graphite Mould		Notched Pencil in Graphite Mould	Sucked-up Silica or Glass Tube	Composition, %				
	0·75 in. dia.	0·56 in. dia.	0·5 in. dia.	0·125–0·25 in. dia.	Total C	Si	P	Mn	S
G.16	5	...	4	7	3·8	1·9	0·08	0·7	0·03
G.17	...	...	8	10	3·1	1·7	0·14	0·6	0·08
G.18	5	...	8	...	3·5	1·4	0·06	0·6	0·09
G.19	7	...	12	8	4·0	1·9	0·06	0·8	0·03
G.20	53	47	...	...	1·9	1·4	0·04	0·7	0·04
G.10	15	15	14	...	3·2	1·2	0·05	0·5	0·14

a tendency to rise above 0·02 ml./hr. This is necessary because, when analysing cast iron, sulphur compounds are distilled into the graphite and can cause high blanks.

ACCURACY OF METHOD

Before any detailed investigation into the effects of gases on cast iron could be started, the accuracy and reproducibility of the method had to be tested. A suitable sampling method had also to be devised to give the gas content of the liquid metal.

The first problem to be investigated was the possible effect of surface gas on the analytical specimen. Sloman[6] had already shown that this effect was greater for grey iron than for steel. Samples of cast iron with different surface/mass ratios, and also vacuum-melted samples, were analysed. A record was also made of the lowest gas contents obtained. The results obtained were not very accurate, owing to the very small volume of gas evolved in many cases, but the following general conclusion could be drawn. The error due to surface gas on a 20-g. cylindrical specimen 1 in. × $\frac{1}{2}$ in. dia. is not likely to be more than 5×10^{-4} % for oxygen, 10×10^{-4} % for nitrogen, and $0{\cdot}5 \times 10^{-4}$ % for hydrogen. These errors, especially for hydrogen, may be increased for coarse-grained or porous materials.

During the investigation into the effects of surface gas it was found that porosity, especially in grey irons, was always accompanied by high and variable gas contents (*see* Table I). This may be due to internal oxidation or even to rusting, or it may be caused by segregation of gas during solidification. To overcome this difficulty, only sound samples are analysed at present.

The next problem was the effect of storage. Table II shows that this effect is negligible for oxygen and nitrogen. However, the error in the determination of hydrogen may well be appreciable, as experiments have shown that hydrogen is evolved on storage under mercury. This is, however, still being investigated.

SAMPLING

To find which type of sample would give the best results, a number of melts were carried out and various types of sample were taken. These included various types of sand-cast and chill-cast specimens. As it had already been shown that porosity gave inconsistent results, the moulds were all designed to give sound castings. In the course of this work it was soon found that all types of chilled sample gave the same results (*see* Table III), so that the simplest type (an open-topped graphite mould giving three cylinders $1\frac{1}{2}$ in. long by $\frac{9}{16}$ in. dia., shown in Fig. 4)

Table IV

VARIATION OF OXYGEN, HYDROGEN, AND NITROGEN ALONG KEEL BLOCKS

Bars cut into 7 pieces, Nos. 1 and 7 being at ends and No. 4 at centre of bar. All results in wt.-% × 10^4

Ref. No.		Sample No.							Composition, %				
		1	2	3	4	5	6	7	Total C	Si	P	Mn	S
G.2*A*	O	15	17	38	36	...	...	...	3·2	1·9	0·05	0·5	0·14
	H	1·2	0·8	1·3	0·8	...	...	...					
	N	48	47	63	54	...	...	...					
G.28	O	19	34	36	...	35	34	...	3·8	1·8	0·06	0·7	0·03
	H	1·0	1·4	1·5	...	1·3	1·5	...					
	N	38	53	38	...	37	37	...					
G.45	O	54	66	61	...	79	...	65	3·6	2·8	0·06	0·8	0·02
	H	2·0	3·2	6·0	...	3·4	...	2·5					
	N	23	42	44	...	22	...	27					
G.52	O	11	...	...	18	15	...	12	3·5	1·4	0·07	0·5	0·08
	H	0·7	...	...	0·6	0·7	...	0·6					
	N	45	...	...	49	47	...	43					

Table V

REPRODUCIBILITY OF RESULTS FROM CHILL-CAST SAMPLES

Chemical composition:
Total C, 3·48%; Si, 1·45%; Mn, 0·54%; S, 0·088%; P, 0·099%

Sample No.	Oxygen	Hydrogen	Nitrogen
	Wt.-% × 10^4		
G.50/1	18	1·1	17
/1	14	1·0	30
/1	17	0·9	24
/2	15	1·3	30
/2	18	0·9	31
/2	19	1·2	31
/3	18	1·1	40
/4	14	1·5	44
/4	13	1·0	32
/4	16	1·5	41
/5	15	1·7	43
/5	15	0·9	26
/6	15	1·5	39
/7	17	0·8	28
/8	18	0·8	27
/8	15	1·1	31
/9	17	0·9	29
/9	17	1·4	36
/9	16	1·3	35
/10	78	1·0	39
/10	15	1·3	39
/11	17	1·4	38
/12	17	1·6	36
/13	17	1·8	37
/14	19	1·3	36
/15	15	1·5	39
/16	15	2·2	33
/17	19	1·8	43

was adopted. Reproducibility tests were carried out along grey-iron keel-block bars (which were chosen because they should be sound), and a variation was often obtained, higher results occurring in the centre of the bar. This may have been due to the structure being coarser at the centre, thus giving a greater surface error. Some results are given in Table IV.

Reproducibility tests were also carried out on the chill samples. The tests consisted of melting 70 lb. of cast iron in an oil-fired crucible furnace, skimming when melted, and plunging to ensure thorough mixing. Seventeen sets of chill samples were then cast in succession. These samples were analysed for oxygen, hydrogen, and nitrogen. The results are given in Table V.

The reproducibilities obtained (ignoring the obviously erroneous result of 78 × 10^{-4} % for oxygen, which was probably caused by entrapped slag) were 16 ± 3 × 10^{-4} % for oxygen, 1·5 ± 0·7 × 10^{-4} % for hydrogen, and 35 +9–11 × 10^{-4} % for nitrogen. These reproducibilities compare very favourably with those obtained by vacuum-fusion during a co-operative study of steel samples which was carried out by the British Iron and Steel Research Association (results not yet published). Good correlation is also obtained with nitrogen contents determined chemically.[7]

A comparison of the results obtained on sand-cast and chill-cast samples from the same metal is given in Table VI. In general, it can be seen that grey irons when sand-cast in the form of keel blocks give higher oxygen results than the chill-cast samples, but approximately the same for hydrogen and nitrogen. This, however, is not the case for white cast irons (*i.e.*, low-silicon material). Here the chill-cast samples often come higher than the sand-cast. These two effects can be explained, although it has not been proved, on the basis of the difference in activity of oxygen in high- and low-silicon irons. Low-silicon irons with high carbon content tend to be 'wild,' *i.e.*, oxygen is evolved as CO on cooling. Unless cooling is very rapid, as in the chilled test pieces, low oxygen results would be obtained. This effect is, however, very much reduced in the case of high-silicon irons.

As a result of these investigations it was decided that the chill-cast samples (*see* Fig. 4) were the most

Table VI

COMPARISON OF OXYGEN, HYDROGEN, AND NITROGEN CONTENTS OF CHILL-CAST AND SAND-CAST SAMPLES

All results in wt.-% × 10^4

Ref. No.	Type of Iron	Sand-Cast			Chill-Cast			Composition, %					
		O	H	N	O	H	N	Total C	Si	P	Mn	S	Mg
G.16	Grey	20	1·2–3·0	18	5	1·0	15	3·8	1·9	0·08	0·7	0·03	...
G.19	Grey	35	2·0	10	8	1·9	12	4·0	1·9	0·06	0·8	0·03	...
G.33B	Nodular	2	1·7	32	2	0·8	34	3·3	2·0	0·05	0·5	0·02	0·08
G.40	Grey	15	0·4	43	6	0·8	43	3·2	1·4	0·12	0·6	0·06	...
G.43	Grey	23	0·9	59	12	0·8	50	3·3	1·3	0·13	0·5	0·10	...
G.20	White	32	1·8	55	49	1·1	61	1·9	1·4	0·04	0·7	0·04	...
G.32	White	55	1·4	20	68	1·8	17	3·2	0·1	0·04	Nil	0·03	...
G.34	White	16	1·7	46	28	1·3	51	3·0	0·1	0·04	0·2	0·03	...

satisfactory for the analysis of cast iron for oxygen and nitrogen. At present, however, very little reliance is placed upon the results for hydrogen. The whole question of the determination and sampling for hydrogen is under investigation.

ANALYSIS OF NODULAR CAST IRON

Numerous samples have been analysed by the above techniques with very satisfactory results. One doubt that arose during the work was in connection with nodular cast iron made by treatment with nickel–magnesium alloy. Very low oxygen contents were obtained ($2–5 \times 10^{-4}$ %), and it was wondered whether MgO, if it were present, would be reduced by carbon under the conditions used. Sloman[3, 5, 8] had already shown that silicon, aluminium, manganese, etc., would be reduced and the same calculations were applied to MgO. These showed that MgO should be reduced completely at 1550° C. To check for complete reduction, other samples were reduced at temperatures up to 1800° C. The same results were obtained and it was felt that the low results obtained are in fact true figures for magnesium-treated iron.

References

1. L. JORDAN and J. R. ECKMAN: *Ind. Eng. Chem.*, 1926, vol. 18, pp. 279–282.
2. E. TAYLOR-AUSTIN: *J. Iron Steel Inst.*, 1941, No. I, pp. 328P–331P.
3. H. A. SLOMAN: 8th Report on the Heterogeneity of Steel Ingots, Spec. Rep. No. 25, pp. 43–62: 1939, London, The Iron and Steel Institute.
4. W. C. NEWELL: *Ibid.*, pp. 97–102.
5. H. A. SLOMAN: 7th Report on the Heterogeneity of Steel Ingots, Spec. Rep. No. 16, pp. 82–100; 1937, London, The Iron and Steel Institute.
6. H. A. SLOMAN and T. E. ROONEY: *J. Iron Steel Inst.*, 1943, No. II, pp. 327P–340P.
7. H. J. WINKLER and B. B. BACH: *Brit. C.I. Res. Assoc., J. Res. Dev.*, 1953, vol. 4, pp. 553–559.
8. H. A. SLOMAN, C. A. HARVEY, and O. KUBASCHEWSKI: *J. Inst. Metals*, 1952, vol. 80, pp. 391–407.
9. B. B. BACH, J. V. DAWSON, and L. W. L. SMITH: *Chem. Indust.*, 1953, No. 48, Nov. 28th, pp. 1279–1280.

Determination of Aluminium in Iron and Steel

By the Methods of Analysis Committee

SYNOPSIS

The determination of aluminium in steel is considerably facilitated by the removal of iron and related elements by the mercury-cathode electrolysis of a sulphuric acid solution. Benzoate and 8-hydroxyquinoline separations have been applied to such an electrolysed solution and a technique of operation has been devised whereby excellent recoveries of aluminium have been obtained with the latter method. Results on synthetic solutions and on steels are provided. 859

ONE of the projects undertaken by the Highly Alloyed Steels and Ferro-Alloys Analysis Sub-Committee* early in 1947 was an investigation into the determination of aluminium. It was appreciated that considerable research on this subject would be required and a fundamental approach was adopted. A bibliography was prepared and two study groups were set up to examine respectively ammonium benzoate and 8-hydroxyquinoline separation of aluminium from solutions containing such amounts of other elements as might remain after a mercury-cathode separation, with the object of obtaining quantitative recovery. In view of its wider application, the technique of mercury-cathode electrolysis has been studied and reported on separately.†

THE BENZOATE SEPARATION

Preliminary work on the benzoate separation was based on information provided by one of the members from which it was shown that a double precipitation with ammonium benzoate from a chloride solution buffered to *p*H4 (bromo-phenol blue) with ammonium acetate gave satisfactory separation of aluminium from equal amounts of chromium, cobalt, nickel, and zinc. This work was extended to solutions containing additional elements such as molybdenum, titanium, tungsten, and vanadium, in the presence of thioglycollic acid. Under these conditions titanium and

* The Constitution of the Sub-Committee at 31.12.52 was: Mr. B. BAGSHAWE (*Chairman*) (B), Brown-Firth Research Laboratories; Mr. C. D. ATKINSON, Sheffield Testing Works Ltd.; Mr. J. W. FLINT, Wm. Jessop and Sons Ltd.; Mr. L. E. GARDNER (B), Edgar Allen and Co., Ltd.; Mr. C. L. GRAYSON (A), English Steel Corporation Ltd.; Mr. E. W. HARPHAM, Richard Thomas and Baldwins Ltd.; Mr. S. HARRISON (A), Kayser, Ellison and Co., Ltd.; Mr. J. D. HILL (B), Bragg Laboratory, N.O.I.D.; Mr. G. M. HOLMES, London and Scandinavian Metallurgical Co., Ltd.; Mr. R. T. POSTLETHWAITE, Samuel Fox and Co., Ltd.; Mr. L. N. TAYLOR, Samuel Osborn and Co., Ltd.; Mr. J. L. WEST, Hadfields Ltd.

The Sub-Committee wishes to record its sincere appreciation of the contribution made to this investigation by the following past members: Mr. E. DYKE (1949–1952), Brown-Firth Research Laboratories; Mr. W. T. ELWELL (A) (1947–1952), I.C.I. Ltd., Billingham Division; Mr. G. MURFITT (1947–1949), Wm. Jessop and Sons Ltd.; Mr. T. E. ROONEY (A) (1947–1948), National Physical Laboratory.

(A—Benzoate Group; B—8-hydroxyquinoline Group).

Paper MG/D/134/53 of the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association, received 17th July, 1953.

† Methods of Analysis Committee, *J. Iron Steel Inst.*, 1954, vol. 174, pp. 29–36.

Table I
RESULTS BY TENTATIVE PROCEDURES
Aluminium recovered, mg.

Analyst	Procedure I		Procedure II			
	0·5 mg. Al Added	10 mg. Al Added	0·5 mg. Al	10 mg. Al	Steels	
					MGS/182	MGS/183
1	5·4*	10·6	5·1*	10·0	...	...
2	0·8 0·5† 0·6‡	... 10·6† 10·1	0·4	9·8	...	...
3	0·6 0·8‡	10·7 10·5‡	0·9	10·7	...	...
4	...	...	1·2	10·0	0·4	1·7

* 5 mg. Al added. † 10 mg. Ti only. ‡ Without chloroform extraction.

vanadium interfered and phosphorus tended to encourage precipitation of many elements with the aluminium, particularly chromium, molybdenum, and tungsten.

Arising from these conclusions, the principle of the method was applied to a typical solution such as would be obtained after mercury-cathode electrolysis, but with deliberately exaggerated amounts of residual elements, as follows:

10 g. of ammonium sulphate
5 mg. of phosphorus (sodium phosphate)
5 mg. of iron (ferrous ammonium sulphate)
5 mg. of nickel (sulphate)
5 mg. of cobalt (,,)
10 mg. of chromium (potassium dichromate)
10 mg. of vanadium (ammonium metavanadate)
10 mg. of molybdenum (ammonium molybdate)
25 mg. of manganese (sulphate)
40 mg. of titanium (acid potassium titanyl sulphate)

with sufficient sulphuric acid to retain all the constituents in solution in a total volume of 300 ml.

Two procedures were used to remove interfering elements before final precipitation of the aluminium, which was added in varying amounts up to 10 mg.

Ammonia Separation

Chromium and manganese were oxidized with ammonium persulphate, manganese was subsequently reduced with hydrochloric acid, ammonium chloride and hydroxide were added, and the precipitate was separated by filtration. The ignited residue was fused with sodium carbonate and extracted with water, the solution was filtered, and the aluminium was precipitated with benzoate. Recoveries tended to be high but little contamination with chromium or titanium was found.

Cupferron Separation

The ammonia separation was carried out as above, the hydroxides were dissolved in sulphuric acid, the solution was cooled to 0° C. and excess cupferron was added. The precipitated complexes and excess cupferron were removed by treatment with chloroform, the aqueous layer was then boiled, and the aluminium was precipitated as before. Satisfactory separation was achieved, but high and variable blanks were found.

8-HYDROXYQUINOLINE SEPARATION

This was first applied direct to a chloride solution without interfering elements. The precipitated quinolate complex was redissolved in hydrochloric acid, an excess of standard potassium bromate/bromide solution was added, and the residual bromine was determined by titrating its iodine equivalent liberated from potassium iodide with standard sodium thiosulphate solution. This procedure provided quantitative recoveries of aluminium down to 0·5 mg.

Having ascertained that the 8-hydroxyquinoline separation was quantitative, work was started on complex solutions. The effect of the following procedures in overcoming the interference of other elements was examined:

(i) ammonia separation
(ii) cupferron separation
(iii) cyanide stabilization
(iv) sulphide separation.

As a result of several series of trials, it was concluded that a cupferron separation stage was required followed by treatment with cyanide and sulphide. If the order of addition of the latter two reagents was reversed, the sulphides could be removed by filtration, but some occlusion of aluminium was suspected. Results by either modification were, however, reasonably satisfactory.

TRIALS OF TENTATIVE PROCEDURES

The preliminary work had therefore resulted in the provision of four techniques, each of which had been shown to give acceptable recovery of aluminium from a solution of the type obtained after mercury-cathode separation. Two of these procedures were now applied to synthetic solutions of similar composition to that already examined,* containing respectively 0·5 and

* In this case, the ammonium sulphate, molybdenum and nickel were omitted, the amounts of manganese, titanium and vanadium increased to 50 mg., 100 mg., and 50 mg. respectively, 7·5 g. of sodium carbonate and 16 ml. of sulphuric acid (sp.gr. 1·84) were added, and the solution was diluted to 450 ml.

10 mg. of aluminium, and to two steels after mercury-cathode electrolysis of solutions of 10 g. of each in sulphuric acid. Brief details of the procedures used are as follows and the results obtained are given in Table I.

Procedure I

To the cold sulphuric acid solution (filtered if necessary), after electrolysis in a mercury-cathode cell, add ammonium hydroxide (1 : 1) until the solution is just alkaline to bromo-cresol purple indicator. Transfer to a water-bath for 15 min., filter through a Whatman No. 541 15-cm. paper and wash with hot ammonium nitrate solution (2%).

Dissolve the precipitate from the paper into the original beaker with warm sulphuric acid (1 : 4), dilute to 150 ml., and then add ammonium hydroxide (1 : 1) until the precipitate formed only just redissolves. Heat the solution almost to boiling point, add 2·5 g. of ammonium persulphate to the clear solution, and boil for 10 min. Dissolve any precipitated hydrated manganese dioxide by small additions of hydrochloric acid (sp.gr. 1·16) and then cool the solution to about 50° C.

Add ammonium hydroxide (1 : 1) until the solution is just alkaline to bromo-cresol purple indicator. Transfer to a water-bath for 15 min., filter, and wash with hot ammonium nitrate solution (2%) until the filtrate shows no visible sign of chromate. Discard the filtrate.

Dissolve the precipitate through the paper into the original beaker by the addition of 50 ml. of hot hydrochloric acid (1 : 1). Wash, adjust the volume to approx. 100 ml., then cool to 5–10° C. Add an aqueous cupferron solution (5%—recrystallized from ethyl alcohol and washed with methylated ether) slowly from a burette, stirring all the time until precipitation of the complexes is complete. Allow to stand in ice water for 10 min., stir occasionally, then transfer to a separating funnel of suitable size. To the original beaker add 15 ml. of chloroform to dissolve any adhering precipitate, and then transfer the solvent to the separating funnel. Extract and remove the cupferron complexes and excess reagent by shaking and withdrawing the chloroform layer. It is advisable to carry out the extraction under running cold water in a sink. Repeat the extraction twice with two further 15-ml. additions of chloroform added *via* the original beaker. Retain the chloroform layers for solvent recovery only, otherwise discard.

Boil the aqueous solution for 5 min., then cool. The solution at this stage should be free from any suspended matter, otherwise it must be filtered. Dilute to 250–300 ml., add 1 g. of ammonium chloride, 20 ml. of 10% ammonium acetate solution, 20 ml. of 10% ammonium benzoate solution, and 2 ml. of bromophenol blue indicator solution. Heat to 80° C., add sufficient hydrochloric acid to dissolve any precipitated aluminium benzoate (the benzoic acid, which precipitates in the cold, is soluble at 80° C.), and add ammonium hydroxide (1 : 1) from a burette, slowly and with shaking, until the indicator just begins to change colour and precipitation *just* begins.

At this point, boil the solution for 1–2 min. when further precipitation takes place giving a granular precipitate. Continue the addition of ammonium hydroxide solution (1 : 1) from the burette until the indicator just gives the red-blue colour characteristic of *p*H 3·5–4. Boil the solution gently for 2–3 min. and allow the precipitate to settle on a water-bath for 30 min. Filter through a Whatman No. 40 paper and wash ten times with hot wash liquor (10 g. of ammonium benzoate and 20 ml. of glacial acetic acid per litre, *p*H 3·8), dry and ignite strongly to constant weight.

Procedure II

To the cold sulphuric acid solution (filtered if necessary), after electrolysis in a mercury-cathode cell, add ammonium hydroxide (1 : 1) until the solution is just alkaline to bromo-cresol purple indicator. Transfer to a water-bath for 15 min., filter through a Whatman No. 541 15-cm. paper, and wash with hot ammonium nitrate solution (2%).

Dissolve the precipitate from the paper into the original beaker with hot hydrochloric acid (1 : 1), add 5 ml. of sulphuric acid (sp.gr. 1·84) and a few drops of nitric acid (sp.gr. 1·42), and evaporate to fumes. Dilute with 75 ml. of water, boil to dissolve salts, and cool to room temperature or below.

Add cupferron solution (5%) slowly, stirring all the time until precipitation of the insoluble complexes is complete. Stir in a little pulp, and filter through a pulp pad. Wash with cold hydrochloric acid (1 : 9) containing a little cupferron solution. Discard the precipitate.

Add 20 ml. of nitric acid (sp.gr. 1·42) to the filtrate and evaporate to fumes; if necessary add further nitric acid until all organic matter is completely destroyed. Cool, and extract the fumed concentrate with 30 ml. of water.

Dilute to 70 ml., add 5 ml. of tartaric acid solution (20%), and neutralize with ammonia (1 : 1) to the change point of methyl red. Add 10 ml. of potassium cyanide solution (10%), heat to 60° C., and add 25 ml. of ammonium sulphide solution. Digest at about 60° C. for 10 min., cool, filter, and wash with ammonium sulphide wash solution. Collect the filtrate in a 400-ml. beaker and dilute to approx. 150 ml. with ammonium sulphide wash solution.

Heat just to boiling point and add dropwise 8 ml. of 8-hydroxyquinoline (5%), agitating the solution vigorously throughout the addition. Digest at 90° C. for 10 min. Without further delay, filter through a pulp pad and wash with hot water.

Dissolve the precipitate from the pad with 100 ml. of nearly boiling hydrochloric acid (1 : 1) and collect the extract in a 500-ml. Taylor-pattern flask. Finally wash the pad several times with hot water and discard. Dilute the solution to approx. 200 ml. and cool. Add three drops of indigo-carmine indicator and titrate with standard bromate solution until the blue tint of the indicator is discharged. Add a further three drops of indigo-carmine, continue the titration with bromate until the solution assumes a clear golden yellow colour, and then add 2–3 ml. excess of bromate. Stopper the flask, shake, and allow to stand for 5 min. to ensure complete bromination.

Remove the stopper, add 10 ml. of potassium iodide solution (20%), and titrate with sodium thiosulphate

until the brown iodine colour is discharged. Add a few drops of starch solution and continue the titration with sodium thiosulphate until the blue starch-iodide colour is just discharged.

It was evident from the results that the benzoate procedure alone did not completely overcome interference, particularly of titanium, although more satisfactory figures were obtained at the lower aluminium level, and it was decided to combine the two procedures into a comprehensive draft by which it was hoped that all co-precipitating elements could be removed from the solution in convenient stages and that the final precipitation of aluminium could thus be made from a practically pure solution without loss.

FINAL TRIALS

The procedure thus modified was again applied to the synthetic solutions and the steels previously examined, with the results given in Table II.

It was considered that, except for the very low aluminium contents, the procedure was quite satisfactory and it was found that improved recovery at the lower levels was obtained by very slow addition of the 8-hydroxyquinoline reagent. With this proviso the method, which is detailed in the Appendix, is recommended for the determination of aluminium in iron and steel after mercury-cathode separation.

APPENDIX—Recommended Method

SOLUTIONS REQUIRED

Ammonium hydroxide (1 : 1)
Hydrochloric acid (1 : 1)
Potassium permanganate (0·5%)
Cupferron (5%)
Hydrochloric acid wash—Dilute 100 ml. of concentrated hydrochloric acid (sp.gr. 1·16) to 1 litre and add 10 ml. of cupferron solution (5%).
Tartaric acid (20%)
Methyl red indicator—Dissolve 0·2 g. of methyl red in 100 ml. of methylated spirits.
Potassium cyanide (10%)
Ammonium sulphide—Pass a rapid stream of hydrogen sulphide gas through 250 ml. of ammonia (1 : 1) for 1 hr.
Ammonium sulphide wash—Dilute 10 ml. of the ammonium sulphide solution to 1 l.
8-Hydroxyquinoline (5%)—Dissolve 25 g. of 8-hydroxyquinoline in 60 ml. of glacial acetic acid, and dilute to about 300 ml. with hot water. Filter through a pulp pad and dilute to 500 ml.
Indigo-carmine indicator—Dissolve 1 g. of indigo-carmine in 100 ml. of water, and filter.
Potassium iodide solution (20%)
Starch solution (0·1%)
Sodium thiosulphate—Dissolve 22 g. of sodium thiosulphate ($Na_2S_2O_3.5H_2O$) in water and dilute to 1 l.
Standard potassium bromate solution (1 ml. = 0·0002 g. Al)—Dissolve exactly 2·4770 g. of potassium bromate and about 50 g. of potassium bromide in water, and make up to 1 l.

PROCEDURE

Separation of Group III Hydroxides

Adjust the volume of the solution obtained after mercury-cathode electrolysis to 250–300 ml., add 1 g. of ammonium chloride, heat to 80° C. and add ammonium hydroxide (1 : 1) from a burette, slowly

Table II

RESULTS BY RECOMMENDED METHOD

Aluminium recovered, mg.

Analyst	0·5 mg. Added	10 mg. Added	MGS/182 (10 g.)	MGS/183 (10 g.)	Remarks
1	0·47 0·46	9·9 10·05	0·5 0·4	1·8 1·7	
2	0·86 0·80 0·76	9·98 10·02			1 mg. added—0·96, 0·96 2 mg. added—1·98, 2·04
3	0·50 0·58	9·70 9·75			
4	0·8 0·5 0·6	10·2 9·8 10·6	0·4 0·5 ...	1·7 1·6 ...	
5	0·5	...			1 mg. added—0·9
6	0·48 0·52 0·52			1·7 1·7 1·9	1 mg. added—0·97, 1·02, 1·02
7	0·6	10·1	0·4 0·4		
8	0·50 0·46 0·36	10·3 9·7 9·6	0·5 0·4	1·9 1·8	

and with shaking, until the solution is just alkaline (Note 1). Boil gently for 2–3 min. and allow the precipitate to settle on a water-bath for 30 min. Filter through a Whatman No. 40 paper and wash ten times with hot water.

Dissolve the precipitate from the paper into the original beaker with hot hydrochloric acid (1 : 1), add 5 ml. of sulphuric acid (sp.gr. 1·84) and a few drops of nitric acid (sp.gr. 1·42) and evaporate to fumes. Dilute with 75 ml. of water, boil to dissolve salts, oxidize with a few drops of nitric acid (sp.gr. 1·42) and boil, cool to 10° C. and add potassium permanganate solution (0·5%) until a pink tinge is just visible in the solution.

Cupferron Separation of Titanium, Vanadium, Iron, etc.

Add cupferron solution (5%) slowly, stirring all the time until precipitation of the insoluble complexes is complete. Stir in a little pulp, and filter through a pulp pad. Wash with cold hydrochloric acid wash solution and discard the precipitate.

Add 20 ml. of nitric acid (sp.gr. 1·42) to the filtrate and evaporate to fumes; if necessary add further nitric acid and fume until all organic matter is completely destroyed. Cool, and extract the fumed concentrate with 30 ml. of water.

Potassium Cyanide Fixation

Dilute to 70 ml., add 5 ml. of tartaric acid solution (20%) and neutralize with ammonium hydroxide (1 : 1) to the change point of methyl red. Add 10 ml. of potassium cyanide solution (10%), heat to 60° C. and add 25 ml. of ammonium sulphide solution. Digest at about 60° C. for 10 min., cool, filter, and wash with ammonium sulphide wash solution. Collect the filtrate in a 400-ml. beaker and dilute to approx. 150 ml. with ammonium sulphide wash solution.

8-Hydroxyquinoline Precipitation

Heat just to boiling point and add dropwise from a burette 8 ml. of 8-hydroxyquinoline (5%), agitating the solution throughout the addition (Note 2). Digest at 90° C. for 10 min. Without further delay, filter through a pulp pad and wash with hot water.

Titration Procedure

Dissolve the precipitate from the pad with 100 ml. of nearly boiling hydrochloric acid (1 : 1) and collect the extract in a 500-ml. Taylor-pattern flask. Finally wash the pad several times with hot water and discard. Dilute the solution to approx. 200 ml. and cool. Add three drops of indigo-carmine indicator, and titrate with standard bromate solution until the blue tint of the indicator is discharged. Add a further three drops of indigo-carmine, continue the titration with bromate until the solution assumes a clear golden yellow colour, and then add 2–3 ml. excess of bromate. Stopper the flask, shake and allow to stand for 5 min. to ensure complete bromination.

Remove the stopper, add 10 ml. of potassium iodide solution (20%) and titrate with sodium thiosulphate until the brown iodine colour is discharged. Add a few drops of starch solution and continue the titration with sodium thiosulphate until the blue starch-iodide colour is just discharged.

STANDARDIZATION

Dilute 100 ml: of hydrochloric acid (1 : 1) contained in a Taylor-pattern flask to approx. 200 ml. and add from a burette 20 ml. of the bromate/bromide solution. Stopper the flask immediately and allow to stand for 5 min. Remove the stopper, add 10 ml. of potassium iodide solution (20%), and titrate with sodium thiosulphate until the brown iodine colour is discharged. Add 10 ml. of starch solution (0·1%) and continue titration until the blue starch-iodide colour just disappears (Note 3).

CALCULATION

Correct the amount of sodium thiosulphate used for its factor relative to bromate, then the net titre registered = 0·0002 g. of aluminium per ml.

NOTES

(1) If insufficient iron is present to act as a 'collector' for the other precipitated hydroxides, about 5 mg. should be added (as sulphate) before neutralization of the solution. Bromocresol purple paper is a suitable indicator for the reaction.

(2) When less than 2 mg. of aluminium is present, this addition must be made as slowly as possible.

(3) A blank determination should be carried through the whole procedure and any necessary correction made. Replicate determinations of aluminium at the 0·1% level should lie within ± 0·002% of aluminium.

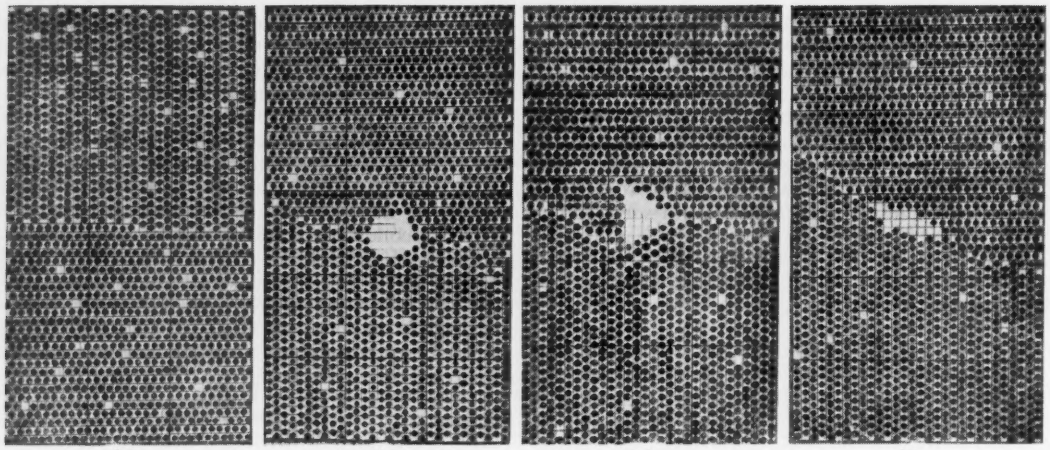
Letters to the Editor

INTERCRYSTALLINE CRACKING OF METALS

Professor Greenwood's recent note on this subject[1] presents a new aspect of the formation of cracks under static tensile test or under fatigue conditions, *viz.*, that they are formed by the aggregation of vacant lattice sites. It is now suggested that the phenomena of crack formation and propagation may be explained by combining this hypothesis with the ideas of Smith[2] concerning interfacial tensions in two-phase alloys, which the writer has used in discussing intercrystalline fracture.[3]

In two-phase alloys there are cases where the dihedral angle is zero, *e.g.*, in copper–bismuth, where the bismuth completely envelopes the copper grains; in copper–lead alloys, where the dihedral angle is above 60°, the lead collects into small triangles at the corners of the grains, and in 10% zinc α-brass–lead alloy, the dihedral angle approaches a value of about 80° and lead takes the shape of spheroids.

It is well known that the harmful effect of lead in pure copper is mitigated by the addition of zinc. A similar ameliorating effect is also found by adding lead to bismuth-embrittled copper. Greenwood[1] has also shown that some solutes inhibit intercrystalline cracking and others accelerate it; *e.g.*, thallium in lead reduces the liability to intercrystalline cracking and tellurium greatly increases it.



(a) (b) (c) (d)

Fig. 1—Models showing suggested distribution of vacant lattice sites

It is generally held that there are many vacant lattice sites in a metal, even in the annealed state, and that stress and temperature either alone or jointly produce a movement of the vacant lattice sites. It is clear from the current conception of dislocations, as presented by Mott,[4] that one does not have to seek sites of cracking on an atomic scale, but rather on a microscopic or macroscopic scale, such as is associated with slip-band formation. If we are to associate cracking with vacant lattice sites, we must therefore attach significance to the overall shape of vacant-lattice-site clusters rather than to the detail contour.

If we assume that the vacant-lattice-site cluster possesses the properties of a second phase in a two-phase alloy, the subject may be studied by means of the model of balls arranged in two orientations (Fig. 1). From these models we can postulate the following:

(i) Under conditions of stress or temperature the vacant lattice sites will migrate with a preference towards the boundary

(ii) The rate and direction of migration will be influenced by the nature of the atoms, stress, and temperature

(iii) Atoms of certain elements will facilitate these movements and some will prevent them, thus allowing or preventing the formation of clusters of vacant lattice sites

(iv) The cracking and consequent failure of the material occurs when the cluster of vacant lattice sites takes a shape with a sharp dihedral angle of less than 60°.

Figure 1*a* shows a model with an arrangement of 1500 balls (atoms) with two orientations with 32 vacant (lattice) sites distributed at random, as visualized in an annealed material.

Figure 1*b* shows another arrangement of 1500 balls with 32 vacant (lattice) sites; a cluster of 20 vacant sites is situated at the change of orientation and the remaining 12 are distributed at random. In this case, the dihedral angle of the cluster of 20 vacant sites is about 180°, and it is suggested that under such conditions the vacant-lattice-site cluster will have the properties of a harmless pore and not that of a crack with tendencies to propagate.

Figure 1*c* shows another arrangement with the same number of balls and exactly the same number of 32 vacant (lattice) sites; a cluster of 20 vacant sites is formed at the change of orientation and the remaining 12 are arranged at random. In this case, the cluster with the shape of an equilateral triangle has a dihedral angle of about 60°. It is suggested that under this condition the crack will not be propagated, but there is a potential weakness, because once the angle becomes less than 60°, the cracking condition would be set up and it will be propagated as the angle approaches 0°.

Figure 1*d* shows another arrangement with the same number of balls and vacant lattice sites; a cluster of 20 vacant sites formed at the change of orientation has a shape whose dihedral angle is about 15°. The 12 remaining are distributed at random. This condition is one of definite weakness and the crack will propagate as the angle approaches a value of 0°.

Using Smith's idea to explain brittle fractures makes it clear that the fracture can be explained by the shape of the structure when viewed on a macroscopic or microscopic or even on a finer scale (since the property of a material depends on the shape, size, and distribution of its constituents) and by their distribution within them. If this were not so, the law of the triangle of forces and the concept of the ' dihedral angle ' would not have the significance it really has.

The author wishes to thank Mr. E. H. Bucknall, Director of the National Metallurgical Laboratory, for his valuable comments.

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1. J. N. GREENWOOD: *J. Iron Steel Inst.*, 1952, vol. 171, p. 380.
2. C. S. SMITH: *Metals Technology*, 1948, vol. 15, Tech. Publ. No. 2387.
3. A. A. KRISHNAN: Symposium on Industrial Failures of Engineering Materials: Jamshedpur, National Metallurgical Laboratory (in the press).
4. N. F. MOTT: *Proc. Inst. Mech. Eng.*, 1952, vol. 166, Ser. A, pp. 413–418.

I am pleased to have the comments of Dr. A. A. Krishnan about my letter on intercrystalline cracking. I am in general agreement with his views as postulated in (i)–(iv), but I do not think this necessarily covers the mechanism of the formation of an intercrystalline crack. Also, it seems unnecessary to introduce the Smith concept of the dihedral angle to a cluster of vacant sites. It seems self-evident that the smaller the

peripheral angle of the cluster is, the greater will be the stress concentration, and it must be remembered that these cracks form in a general direction transverse to the tensile-stress axis.

In a later letter[1] than that quoted by Dr. Krishnan, I have shown the presence of microscopic cavities in the grain boundaries of α-brass, and in a still later publication[2] more details are given about the conditions under which these form in copper, brass, and magnesium.

The surface of the facets in a fracture formed by intergranular cavitation is covered with microscopic 'pockmarks,' indicating that the intercrystalline cracks form by the multiplication and ultimate 'running together' of these minute cavities.

It is my view that these cavities are nucleated by the coming together of sufficient vacant sites to form a stable 'hole.' The cavities then grow to microscopic or even macroscopic size (i) by absorption of further vacancies, and (ii) by stress concentration.

Although the dihedral-angle concept is not considered applicable to the formation of intercrystalline cracks from 'vacancy cavities,' there is strong evidence to suggest that it is most important when failure occurs under stress in contact with a liquid metal.

It is hoped that this evidence will shortly be published.

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1. J. N. GREENWOOD: *J. Inst. Metals*, 1952, *Bull.*, vol. 1, No. 14, p. 120–121
2. J. N. GREENWOOD: *Acta Metallurgica* (in the press).

IS M_s TEMPERATURE INFLUENCED BY COOLING RATE?

There is a widely held belief that the temperature (M_s) at which martensite begins to form, when cooling a steel from the austenitic state, is constant for a given steel composition. This implies that the M_s temperature of a steel is independent of cooling rate, which has been assumed in various formulæ used for calculating the M_s temperature.

In a recent investigation[1] the transformation characteristics of a low-alloy manganese–molybdenum steel under conditions of continuous cooling were examined in a rapid action dilatometer, and it was shown that the temperature (M_f) for *completion* of martensitic transformation during continuous cooling was influenced by cooling rate—the higher the cooling rate, the lower the M_f temperature. This suggested that the M_s temperature might also be dependent on cooling rate, and this has now been investigated at B.W.R.A., using a high-alloy steel.

The rapid-action dilatometer was used to examine the transformation characteristics of a 3½% Ni–Cr–Mo steel during continuous cooling. The dilatation specimens were cut from 0·8-in. thick plate in the hardened and tempered condition and having the following composition:

C, %	0·31	S, %	0·010	Cr, %	0·82
Mn, %	0·47	P, %	0·019	Mo, %	0·56
Si, %	0·31	Ni, %	3·40	V, %	0·11

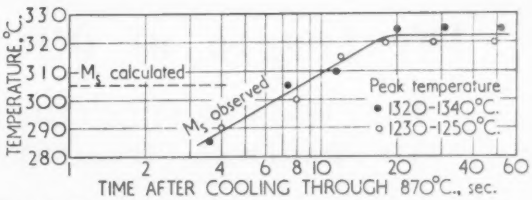

Fig. 1—Effect of cooling rate on observed M_s temperature of 3½% Ni–Cr–Mo steel

The dilatation tests were made on small tubular specimens, using a high-frequency induction heater and a special gas-quench apparatus as described in the earlier paper.[1] The M_s temperature was measured direct from the dilatation curve, and the values observed are considered to be accurate to ± 5° C. Specimens were heated to two peak temperatures and were cooled at different rates to simulate the effect of welding on the plate material. The peak temperatures were approximately 1240° and 1330° C., and the heating times were very short, being about 7 and 8 sec. respectively.

The results are shown in Fig. 1, in which the M_s temperature is plotted against the time taken to cool to M_s. These results show conclusively that for the steel in question the temperature of M_s is influenced by cooling rate. The M_s temperature varies from about 325° C. at low cooling rates to about 285° C. at high cooling rates—a range of 40° C. It is interesting that the calculated value of M_s obtained from the formula* of Nehrenberg[2] is 305° C., which lies in the middle of the observed range.

It is apparent from Fig. 1 that the peak temperature to which the steel is heated has little effect on the M_s temperature. It is also considered that the M_s temperature really depends on cooling time and is not an effect of different austenitizing times,† since the use of a higher peak temperature resulted in a longer austenitizing time but little change in M_s temperature.

Finally, it is suggested that possibly the influence of cooling rate on M_s temperature applies to steels in general, although for lower-alloy steels very high cooling rates may be required to depress the M_s temperature. This effect is indicated in the 3½% Ni–Cr–Mo steel by a levelling of the curve with respect to temperature (*see* Fig. 1) at the lower cooling rates. The results given here indicate how the use of isothermal transformation diagrams to predict results obtained under conditions of cooling can be somewhat misleading.

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1. C. L. M. COTTRELL: *J. Iron Steel Inst.*, 1954, vol. 176, pp. 273–282 (this issue).
2. A. E. NEHRENBERG: *Trans. Amer. Inst. Min. Met. Eng.*, 1946, vol. 167, pp. 494–498; *Metals Technology*, 1946, vol. 13, Part 2, Sept., Tech. Publ. No. 2059, pp. 37–40.

* M_s (° F.) = 930 − 540C% − 60Mn% − 40Cr% − 30Ni% − 20Si% − 20Mo%.

† When the cooling time below 870° C. is increased the austenitizing time is also increased to some extent, as the gas quench operates from peak temperature and consequently affects the cooling rate at high temperatures.

The Length of Oil and Gas Flames

EXTENSION OF FREE FLAME RELATIONSHIPS TO PRACTICAL CONDITIONS

By A. L. Cude, B.Sc., A.M.I.Chem.E.

SYNOPSIS

The following general equation for the length of free turbulent jet flames has been deduced from the theory of jets and confirmed by experiment:

$$L = 83\,\frac{(1 + r_t)}{R}\sqrt{\frac{qs'}{u}}$$

This equation can be applied to fuels of widely differing calorific value, liquid and gaseous. A relationship has been found by which this length can be corrected for the effect of the combustion air momentum, which shortens the flame considerably when it is greater than the fuel jet momentum. A further correction for the elongation due to limited excess air has been deduced from the results of cold model experiments.

The length of a straight jet flame should not exceed 3·5 chamber diameters; if it does, interference from the walls reduces the combustion rate and increases the risk of bad combustion.

Swirling flames expand more rapidly and are affected earlier by the walls, but are not much shorter than straight flames. It is recommended that such flames should not be longer than half a chamber diameter. 870

Introduction

THE combustion of a fuel involves two processes; the fuel has to be mixed with the combustion air before the chemical reactions which comprise combustion can take place. Combustion will occur as soon as air, fuel, and active reaction carriers from a region where combustion is already taking place are mixed in suitable proportions. Since the chemical reactions are very rapid at flame temperatures, it is reasonable to assume that these occur within a very short period after the combustible mixture is formed, so that the rate of combustion, and therefore the flame length, is mainly determined by the rate of the mixing process. In a previous paper* the theory of mixing in turbulent jets was used to derive an equation relating the length of a free turbulent jet flame to the flow conditions at the nozzle. This equation was found to hold for vertical oil and gas flames in free air, provided that the initial momentum of the jet was large compared with that resulting from the buoyancy force acting on the flame.

In this paper, a modified form of the flame length equation has been obtained, applicable to fuels of widely varying calorific value, and also relationships to correct the free flame for the different conditions found in a combustion chamber.

List of Symbols

K	Dimensionless coefficient
k	Empirical coefficient, $\sqrt{}$(cu. ft./lb.)
L	Flame length, ft.
L_F	Calculated free flame length, ft.
m	Mass flow rate of fuel, lb./sec.
M	Mass flow rate of air, lb./sec.
q	Volumetric flow rate of jet fluid,† cu. ft./sec.
r_t	Theoretical air/fuel ratio for complete combustion, lb./lb.
R	Ratio of jet fluid to fuel, lb./lb.
s	Average gas density in mixing zone, lb./cu. ft.
s'	Density of jet fluid at nozzle, lb./cu. ft.
u	Velocity of discharge of jet fluid, ft./sec.
U	Velocity of air, ft./sec.

SCOPE OF THE EXPERIMENTAL WORK

The experiments were designed to investigate the following factors:

(i) Variation of fuel calorific value
(ii) Interference with the free jet by the walls of the combustion chamber
(iii) Restricted excess air
(iv) Combined action of the gas stream and air stream on the mixing process
(v) Swirling air flow in a combustion chamber.

Only town gas was used as a fuel, the variation in calorific value required for (i) being obtained by diluting the gas with nitrogen. Since a close similarity of behaviour between gas and oil flames was found in the earlier work, it was considered unnecessary to repeat this investigation with oil.

APPARATUS

To study the effect of variable gas calorific value, a simple jet burner was set up vertically in the open, with a scale arranged for the measurement of the flame height. Two rotameters were used to measure the town gas and nitrogen, which were mixed in the tube leading to the burner. The pressure at the burner was measured by a water manometer.

The density of the town gas, which was required to evaluate the experimental results, was obtained by means of an effusion-type specific-gravity meter.

* A. L. Cude, *J. Iron Steel Inst.*, 1953, vol. 175, pp. 304–312.

† The jet fluid is that stream of fluid which supplies the momentum flux controlling the mixing process. According to the type of burner, it may be air, fuel, steam, or a mixture of air and fuel or steam and fuel.

Paper PE/A/40/53 of the Fuel Committee of the Plant Engineering Division of B.I.S.R.A., received 2nd November, 1953. The views expressed are the author's, and are not necessarily endorsed by the Committee as a body.

Mr. Cude, formerly in the Fuel Technology Section of the Association's Plant Engineering Division, is now with I.C.I., Billingham Division.

For those experiments requiring a combustion chamber, this was built of insulating bricks and tiles. These were used so that temperatures approximating to those found in practice could be obtained without the need for an inconveniently massive structure. To allow easy modification the bricks were not cemented, air infiltration being reduced by restricting the flue to maintain a small positive pressure. The chamber was 9 in. square in cross-section, and had a maximum length of 6 ft.

Air was admitted to the combustion chamber by the secondary-air nozzle described in the previous paper. This comprised an annular air nozzle with provision for both straight and swirling air flow, and interchangeable nozzles to give three different final orifices. Gas was admitted through jets in the inner tube of the annular air nozzle. Orifice meters were used for the measurement of gas and air flows.

EXPERIMENTAL RESULTS

Variable Calorific Value

Net calorific values between 160 and 450 B.Th.U./cu. ft. were obtained by the use of suitable mixtures of town gas and nitrogen. Lower calorific values were impracticable because the flame was unstable at velocities sufficient to ensure a turbulent jet. Gas pressures varying from 0·8 to 2·4 in. W.G. were used, giving velocities between 60 and 125 ft./sec.

In the previous paper an equation was derived for the length of a free jet flame:

$$L = \frac{K}{R}\sqrt{\frac{qs'}{us}} = \frac{Km}{\sqrt{(mus)}} .$$

In the derivation of this equation it was indicated that the value of K might be proportional to the ratio of the total flow at the tip of the flame to the fuel flow. This ratio cannot be less than $(1 + r_t)$, where r_t is the theoretical mass ratio of air to fuel for complete combustion.

The average density s can only be given an arbitrary value, and, following the procedure of the previous paper, it has been combined with the empirical constant, which now has dimensions. The form of equation adopted for correlating the experimental results in Fig. 1 is

$$L = k(1 + r_t)\sqrt{\frac{qs'}{u}} .$$

In these experiments the fuel is also the whole of the jet fluid, so that $R = 1$.

Statistical correlation of the data gives the best value of k as 83 in lb.ft.sec. units.

This equation should be of general application to any straight jet flame, whatever the fuel and the nature of the jet fluid. For example, consider the outside mixing oil burner described in the previous paper. For gas oil $r_t = 14{\cdot}4$, so that the coefficient is $83(1 + 14{\cdot}4) = 1280$.

The experimentally determined value of the coefficient was 1380, a fairly small difference which may be due to the frictional resistance of the oil burner. Alternatively, a difference in flame temperature of about 300° C. could account for the difference through its effect on the average flame density, which is included in the coefficient.

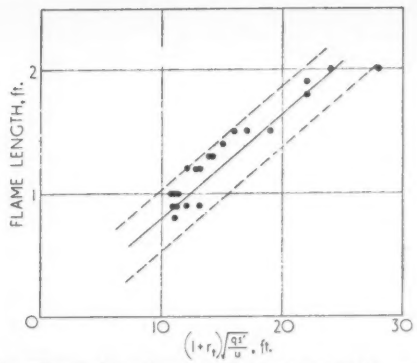

Fig. 1.—Flame lengths with fuel of variable calorific value. (The broken lines represent 95 % confidence limits)

In the experimental flames the temperature was about 1200° C. To allow for the effect of flame density in cases where the flame temperature is known to be higher than this, the following values are suggested:

Approximate Flame Temperature	k
1500° C.	91
1700° C.	96

Interference from Walls of Combustion Chamber

Interference with the free jet by the walls of the combustion chamber produced a marked change in the appearance of the flame. The narrow, fast-moving jet broke down into a lazy, slow-moving flame, less bright in colour than the free jet. This flame occupied the whole width of the furnace, but it was stratified and generally occupied only the upper third of the combustion chamber. There was a marked tendency to smoke formation. The transition between the two types of flame was observed for nine flames with differing jet diameters and flow rates and was found to occur at an average of 3·6 chamber diameters from the nozzle, with a range of 2·7–4·7 diameters.

This suggests that to obtain a hot flame and complete combustion, the flame length should not exceed 3·5 chamber diameters.

Effect of Limited Excess Air

It proved to be impracticable to carry out direct experiments on flames because of the difficulty of obtaining close control of the excess air and at the same time providing adequate observation ports. Some data have, however, been obtained on cold model experiments.* In the cold model, flame length is defined in terms of the axial concentration of the stream representing the fuel. Comparison of the results given by real and model free jet flames indicated that the visible flame length was 2·2 times the length in which the axial air/fuel ratio in the model reached the theoretical value for complete combustion, and that this relation was fairly constant for a wide range of conditions. Assuming that it also remained

* M. W. Thring and M. P. Newby, 4th Symposium (International) on Combustion, pp. 789–796: 1953, Baltimore, Md., The Williams and Wilkins Co.

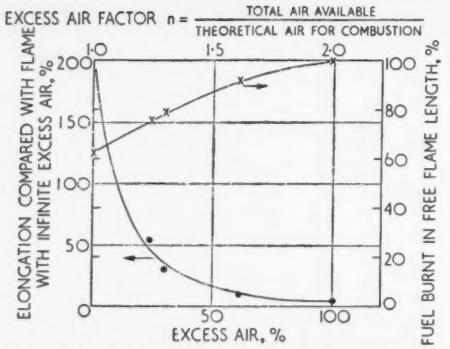
EXCESS AIR FACTOR n = TOTAL AIR AVAILABLE / THEORETICAL AIR FOR COMBUSTION
ELONGATION COMPARED WITH FLAME WITH INFINITE EXCESS AIR, %
FUEL BURNT IN FREE FLAME LENGTH, %
EXCESS AIR, %

Fig. 2—Effect of restricted excess air on jet flames

constant when excess air was restricted, the cold model data were used to construct Fig. 2.

In Fig. 2, one curve connects the relative elongation of the flame compared with a free jet and the percentage excess air. The other curve shows the percentage fuel burnt in the length corresponding to the free jet length. With the exception of the long flames given by theoretical air, the model flames were all less than 3·5 chamber diameters long.

Combined Action of Gas Jet and Air Stream

Gas nozzles were fitted into the secondary-air nozzle and a number of gas rates and nozzle sizes were used. The furnace chamber was less than four diameters long and excess air was allowed to enter so that the restrictions of the two preceding sections do not apply. The results obtained are shown in Fig. 3, in which L/L_F is plotted against mu/MU, where

L = observed flame length
L_F = free flame length for the gas jet, calculated from the equation on p. 271
MU = (mass flow rate)(velocity) = momentum flux of the air stream
mu = (mass flow rate)(velocity) = momentum flux of the gas stream.

Statistical correlation shows a good fit (correlation coefficient = 0·96) between the data and the curve

$$\log \frac{L}{L_F} = 0{\cdot}4 \log \frac{mu}{MU} + 0{\cdot}03 \pm 0{\cdot}065.$$

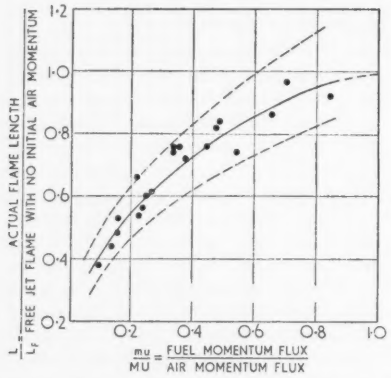

Fig. 3—Effect of air momentum on the length of a jet flame. (The broken lines represent 95% confidence limits)

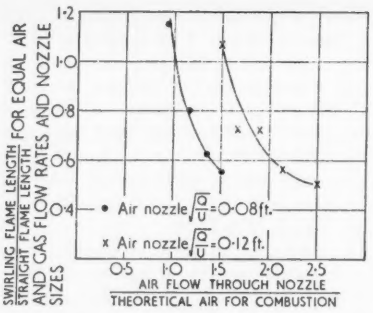
SWIRLING FLAME LENGTH / STRAIGHT FLAME LENGTH FOR EQUAL AIR AND GAS FLOW RATES AND NOZZLE SIZES
• Air nozzle √(a/c) = 0·08 ft.
x Air nozzle √(a/c) = 0·12 ft.
AIR FLOW THROUGH NOZZLE / THEORETICAL AIR FOR COMBUSTION

Fig. 4—Straight and swirling enclosed flames compared

Gas pressures varied from 0·4 to 3·0 in. W.G. and air pressures from 0·1 to 1·0 in. W.G.

This equation is only applicable where both air and fuel form turbulent jets. It applies to a jet burner used in conjunction with forced draught, but not to low-pressure gas burners where the flame is controlled only by the air stream.

In forced-draught burners the air does not usually have a higher velocity than the fuel jet, but it may well have a greater momentum because of its greater mass. These results show that when the air momentum exceeds the fuel momentum it may have a marked effect on the flame length.

Swirling Air Flow in a Combustion Chamber

The swirling flame expanded very rapidly and touched the chamber walls within half a chamber diameter. The swirling flow persisted for two or three chamber diameters, giving a hollow cylindrical flame, but beyond this the flow broke down into a slow diffusion flame.

In Fig. 4 swirling and straight flames are compared. Except at high excess air ratios the swirling flame was not much shorter than the straight flame. Because it occupied the outer annulus of the combustion chamber instead of the core, its volume was appreciably greater. The intensity of combustion must therefore have been less, a conclusion supported by the markedly higher luminosity of the flame. The size of the air nozzle has a large effect, the smaller nozzle needing considerably less excess air for a given flame length.

In Fig. 5 the enclosed swirling flame is compared with a free flame. The enclosed flame is longer than the free flame, but the effect is considerably less for the smaller nozzle than for the larger.

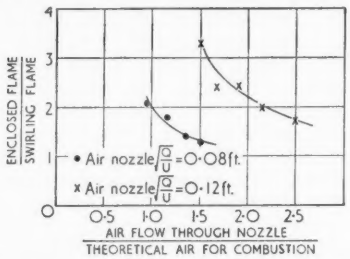
ENCLOSED FLAME / SWIRLING FLAME
• Air nozzle √(a/c) = 0·08 ft.
x Air nozzle √(a/c) = 0·12 ft.
AIR FLOW THROUGH NOZZLE / THEORETICAL AIR FOR COMBUSTION

Fig. 5—Comparison of enclosed and free swirling flames

These effects are probably connected with the early occurrence of wall interference. It is possible to obtain very short flames under free flame conditions, mainly because the great stability of swirling flames allows the use of high air velocities. If it is required to use this type of flame, the chamber must be large enough to avoid wall interference. The diameter of a free swirling flame is nearly as great as its length, so a minimum chamber diameter of two flame lengths is suggested.

CONCLUSIONS

(1) A modified equation is given for the calculation of the length of free jet flames. The equation is applicable to gases of widely varying calorific value and to liquid fuels.

(2) Relationships are given to correct the free flame length for the following conditions found in practice:

(i) The air momentum is large enough to increase the mixing rate; this occurs when the air momentum is greater than the gas momentum.

(ii) Limited excess air.

(3) With straight jet flames, interference from the walls occurs after about 3·6 chamber diameters, causing a reduction in combustion rate and a tendency to stratification and smoking. It is recommended that flame lengths should not exceed 3·5 chamber diameters.

(4) With swirling flames, interference from the walls occurs within half a chamber diameter and leads to a reduction in combustion rate. It is recommended that the flame length should not be greater than 0·5 chamber diameters. Free swirling flame lengths can be calculated from the equation in the previous paper.

Effect of Hydrogen on the Continuous-Cooling Transformation Diagram for a Manganese–Molybdenum Steel

By C. L. M. Cottrell, M.Sc., Ph.D.

SYNOPSIS

Continuous-cooling transformation diagrams have been produced for a commercial manganese–molybdenum steel using a rapid-action dilatometer. These diagrams cover the range of cooling rates occurring during the normal arc-welding process and have been observed for the steel both with and without supersaturation with hydrogen. A marked change in the diagram is observed on addition of hydrogen.

The results of these tests agree with the previously observed critical end-of-transformation temperature for a series of experimental low-alloy steels. A comparison is made between the continuous-cooling transformation diagram and an isothermal transformation diagram for a similar steel. The effect on subsequent transformation of variations in austenitizing time, of peak temperature, and of degassing the steel before tests has also been studied.

The effect of hydrogen on transformation of the manganese–molybdenum steel during cooling at welding rates is discussed with reference to its probable effect on hard-zone cracking. 863

Introduction

THE first part of this investigation[1] indicated that the presence of hard-zone cracking when arc-welding certain low-alloy Mn–Ni–Cr–Mo steels could be related to the temperature for completion of austenite transformation during cooling of the heat-affected zone. In this work, however, the progress of transformation of austenite was observed mainly for one cooling cycle, and the results were related to those obtained when welding the steels with a single type of electrode.* It has been shown elsewhere[2–5] that when an alloy steel is arc-welded with different types of electrode, or with the same electrode and different heat inputs, the incidence of hard-zone cracking is altered.

In some previous work,[5] results were obtained when welding a low-carbon Mn–Mo steel with different types of electrode under various known thermal conditions in the Controlled Thermal Severity (C.T.S.) weldability test. It was therefore decided to produce the continuous-cooling (C.C.) transformation diagram for this steel, using a rapid-action dilatometer.[1] The cooling rates used to produce the diagram would be similar to those in the weldability tests, which would enable the relationship between the transformation of austenite during cooling and the incidence of hard-zone cracking with different types of electrode to be observed.

In addition, a comparison would be made of the C.C. diagram with the isothermal diagram for a similar steel, since such a curve was available in the literature[6] for steel type B.S.970 En 13. In making this comparison it was hoped to observe whether the results obtained by Grange and Kiefer[7] could be applied for high cooling rates.

* Rutile coated, high hydrogen content.

Report No. FM8/89 of the British Welding Research Association, received 18th August, 1953.

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Table I

ANALYSIS AND MECHANICAL PROPERTIES OF STEEL USED

Steel	C, %	Si, %	S, %	P, %	Mn, %	Ni, %	Cr, %	Mo, %	H, ml./100 g.
Mn–Mo	0·19	0·014	0·027	0·023	1·30	0·13	0·10	0·25	0·2
En 13	0·19	0·14	0·012	0·026	1·37	0·56	0·20	0·31	...

Steel	Proof Stress, tons/sq. in.			U.T.S., tons/sq. in.	Elong. on $4\sqrt{A}$, %	Red. in Area, %	Average Hardness Using 10-kg. Load, D.P.N.
	0·02%	0·3%	0·5%				
Mn–Mo	20·8	27·0	28·8	39·4	26	56	185

In view of the work by Wheeler and Kondic[8] on the ductility of steel after heating to high temperatures, it was also decided to study the effect of heating to various peak temperatures on the progress of transformation of austenite.

Because of the hydrogen theory advanced some years ago by Hopkin,[9] and the improved resistance to hard-zone cracking obtained when welding with low-hydrogen electrodes,[2–5] it was decided to produce a transformation diagram for the steel supersaturated with hydrogen. This diagram could then be compared with that obtained for the untreated steel, to determine the effect of hydrogen.

The next stage of the investigation will deal with the effect of hydrogen on the mechanical properties of simulated weld heat-affected zones in the Mn–Mo steel.

EXPERIMENTS

Material

The low-carbon Mn–Mo steel used in this investigation was produced in an 80-ton basic open-hearth furnace. The steel was grain-controlled with aluminium and cast in inverted moulds with hot tops. Additions of molybdenum were made in the furnace, and addition of manganese and silicon were made in the ladle. The ingots were cogged to slabs and the slabs were reheated before rolling into plates.

The steel was supplied in the form of plate $\frac{1}{2}$–$\frac{5}{8}$ in. thick; its analysis and mechanical properties are given in Table I.

Technique

In the dilatometer used in the earlier investigation[1] a temperature variation along the specimen was observed, which would be accentuated when very high cooling rates were used. For this reason, a new dilatometer was constructed to contain a shorter specimen, $\frac{1}{4}$ in. long × 0·225 in. outside dia. × 0·150 in. inside dia. The production of a uniform temperature along the specimen during cooling was assisted by shielding the gas-inlet end of the specimen from the quenching gas, by cementing a short length of silica tube over the push rod (*see* Fig. 1).

Dilatation tests made on untreated steel specimens were carried out as described in the previous report.[1] For those tests made on hydrogen-treated specimens a new technique was used. The specimens were first charged electrolytically with hydrogen according to the method used by Mallet and Rieppel.[10] The electrolysis was carried out for 1 hr. with a current density of 1 amp. per sq. in. of specimen surface. Each specimen was charged three times to ensure that it was fully saturated with hydrogen, for it has been observed that a single electrolysis treatment will not fully saturate a steel specimen, probably owing to poisoning of the surface with the longer electrolysing times involved. Typical results for gas evolution after consecutive charges on several specimens of the Mn–Mo steel (*see* Table II) indicate the desirability of charging each specimen at least twice.

The amount of diffusible hydrogen in the specimen after three treatments was about 14 ml.* per 100 g. of steel when tested 1 min. after removal from the electrolytic bath. This amount was reduced to about 12 ml. per 100 g. 5 min. after electrolysis. This value compares favourably with that for a weld made with a typical B S.1719, Class E317 rutile-basic-coated

Table II

HYDROGEN EVOLUTION AFTER SUCCESSIVE ELECTROLYTIC TREATMENTS

Electrolysis	Hydrogen Evolved Under Paraffin at 25° C. in 24 hr., ml./100 g. of steel
First	9·5–10·5
Second	12·5–14·5
Third	12·5–14·5

* The gas evolved in this way can only be hydrogen. The evolution was measured starting from zero at 1 min. after cessation of electrolysis. The values quoted have been corrected for solution of hydrogen in the paraffin, as later tests using cold vacuum extraction have shown that about 20% of the evolved hydrogen is dissolved.

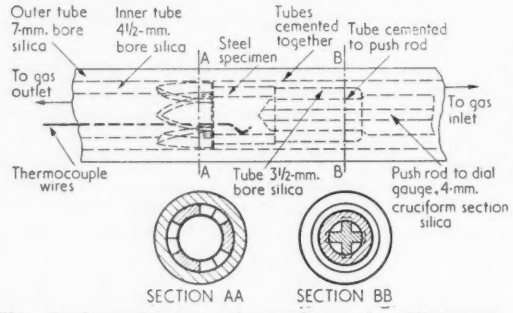


Fig. 1—Arrangement of specimen in dilatometer. Specimen length $\frac{1}{4}$ in.

Table III

CONDITIONS USED TO SIMULATE THE VARIOUS WELDING EFFECTS IN DILATATION SPECIMENS

Heating Atmosphere	Cooling Rate Code	Peak Temp., °C.	Austenitizing Time, sec.	Cooling Time, 870–300° C., sec.	Leg Length of Fillet Weld on ½-in. Plate for Equivalent Conditions, in.
Nitrogen	A	1245	4·0	4·0	$\frac{5}{32}$
,,	B	1230	4·3	7·5	$\frac{3}{16}$
,,	C	1230	5·3	13·2	$\frac{1}{4}$
,,	D	1235	6·5	25	$\frac{5}{16}$
,,	E	1245/1240	7·8/7·6	38/38	$\frac{13}{32}$
,,	F	1235	8·7	55	...
,,	C	1345	6·6	13·3	...
,,	C	1030	2·9	12·5	...
,,	C	1225	8·5	13·2	...
,,	C	1230	22·8	14·5	...
Hydrogen	A	1230 approx.	...	5·0	$\frac{5}{32}$
,,	B	1210	7·0	7·4	$\frac{3}{16}$
,,	C	1220/1230	9·6/9·5	16·8/16·0	$\frac{1}{4}$
,,	D	1220	9·9	30	$\frac{5}{16}$
,,	E	1220	10·5	42	$\frac{13}{32}$
,,	F	1220	13·3	61	...

electrode, which yielded about 14 ml. of diffusible hydrogen per 100 g. of melted metal.[11]

After the third electrolysis certain specimens were inserted in the dilatometer. The dilatometer tube was inserted in the heating coil of a H.F. heater,[1] and a small flow of hydrogen was passed through the dilatometer and burnt at the outlet. The rapid heating (about 1 sec. to reach 750° C.) helped to retain* the excessive hydrogen in the specimen. When the desired temperature was reached, the nitrogen gas quench described previously[1] was used to cool the specimen at a high cooling rate. The specimens were then transferred to the gas evolution apparatus, and about 1 ml. of gas per 100 g. of metal was evolved at 25° C. This result showed that the specimens contained an amount of hydrogen above the 'solubility limit' after the thermal treatment, and the method was therefore suitable for studying the effect of hydrogen on the transformation characteristics of the steel. To determine the total hydrogen a vacuum heating apparatus was used and the average content was found to be 1·7 ml./100 g. This value, when compared with the value of 0·2 ml./100 g. in the as-received steel, showed that a considerable amount of hydrogen was retained during cooling to room temperature at a high cooling rate.

Dilatation Tests

Rapid dilatation tests were made on the untreated steel by heating the specimens in nitrogen to various peak temperatures and cooling at various rates (*see* Table III). The different cooling rates were obtained by varying the gas pressure, cylinder volume, and nozzle size as described in the previous experiments.[1] Certain tests were duplicated for confirmation.

A test was also made to determine whether residual gas in the steel had any effect upon the transformation of austenite during continuous cooling. For this purpose a specimen was degassed by heating *in vacuo* (0·004–0·005 mm. of Hg) for 3½ hr. at 640–650° C., followed by heating for ½ hr. at 870–880° C. and cooling *in vacuo* to 100° C. The steel specimen then had a hardness of 220 D.P.N., which was slightly greater than the value for as-received material. The dilatation test was made by heating the specimen to about 1220° C. in nitrogen, and cooling at rate *C*.

Dilatation tests were also made on hydrogen-treated specimens. These tests, which were begun exactly 5 min. after the third electrolytic treatment was completed, were made by heating the specimens in an atmosphere of hydrogen to the standard peak temperature, and cooling in nitrogen (*see* Table III). A duplicate test was made with cooling rate *C*.

Diamond pyramid hardness tests were made in the longitudinal direction, on the surface of the untreated specimen cooled at rate *D*, and the average variation from end to end of the specimen was only 8 units. Cooling rate *D* was in the critical transformation range, where a small change in cooling rate would produce a considerable change in hardness. Thus this result indicated that there was little variation in cooling rate along the length of the dilatation specimen.

After the rapid dilatation test, each specimen was sectioned transversely, examined microscopically, and hardness tested.

DISCUSSION OF RESULTS

Transformation Behaviour Using Various Cooling Rates, and the Effect of Hydrogen

From the results obtained in the dilatation tests made on the untreated steel, using the standard peak temperature of about 1230° C., a continuous-cooling time/temperature/transformation diagram was constructed. This is shown in Fig. 2*a*, in which the progress of both the intermediate and the martensitic transformation is indicated.

With the highest cooling rates (*A* and *B*) the transformation during cooling was completely martensitic. In the tests using cooling rates *C*, *D*, and *E* the transformation of austenite was duplex, giving both intermediate and martensitic products. Using the lowest

* At high temperatures most of the hydrogen involved is soluble in the steel.

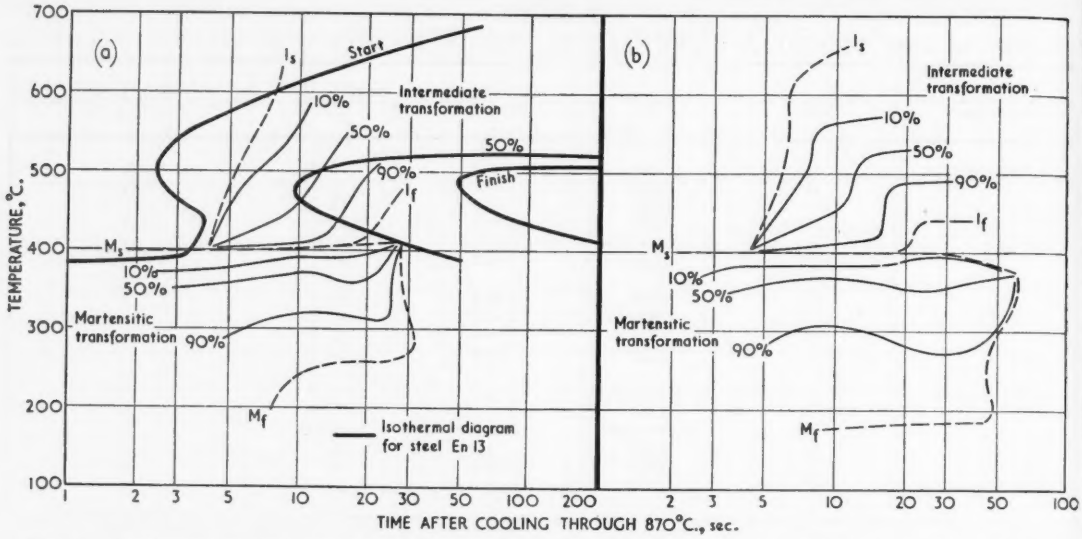


Fig. 2—Continuous-cooling transformation diagrams for Mn–Mo steel: (*a*) Untreated steel (peak temperature approx. 1230° C.); (*b*) hydrogen-treated steel (peak temperature approx. 1220° C.). Figure 2*a* also shows the isothermal transformation diagram for En 13 steel

cooling rate, *F*, the transformation of austenite took place in the temperature range 400–600° C., thus giving an intermediate product.

The line for 50% intermediate transformation (Fig. 2*a*) occurs about mid-way in temperature and time between the start and finish of this transformation, indicating that the transformation progresses steadily. It should be noted that in this diagram the intermediate and martensitic transformations are each treated separately: the start, 10%, 50%, 90%, and finish of transformation are plotted for each product. This distinction is not so clear in the isothermal transformation diagram. It is also simpler to plot the results of isothermal work, since, at a given temperature, there is usually only one type of transformation product, and the progress of martensitic transformation is not recorded.

The line for 50% martensitic transformation is nearer to the M_s line than to the line representing completion of transformation; therefore, in this instance, the martensitic transformation starts rapidly and becomes more sluggish as transformation continues. When the martensitic transformation is nearing completion there is a pause in the transformation (*see* Fig. 3*a*, from 290° to 270° C.) until a lower temperature is reached, when transformation is

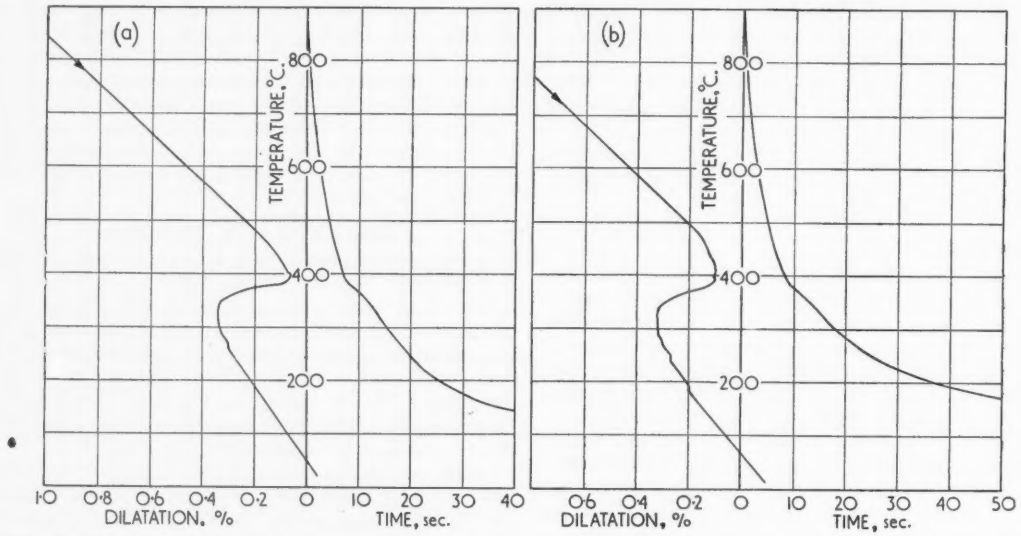


Fig. 3—Dilatation and cooling curves for Mn–Mo steel, using cooling rate C: (*a*) Untreated steel (peak temperature 1230° C.); (*b*) hydrogen-treated steel (peak temperature 1220° C.)

completed over a relatively short temperature range.* This effect is also apparent with the lower cooling rates, although with less martensitic transformation.

In all the dilatation tests on untreated steel, the M_s point was between 400° and 415° C., which shows that cooling rate has little effect on the M_s temperature of this steel at the cooling rates involved. The temperature for completion of martensitic transformation, however, is dependent upon cooling rate and varies from 205° C. for the highest rate (*A*) to 345° C. for rate *E*.

The results of dilatation tests made on hydrogen-treated Mn–Mo steel heated to the standard peak temperature were used to construct another C.C. transformation diagram (*see* Fig. 2*b*). This differs considerably from that for the untreated material (Fig. 2*a*). The martensitic transformation is more sluggish in the hydrogen-treated steel, and there are more pauses during this transformation (*see* Fig. 3*b*). This effect is more marked with cooling rate *D*, when the martensitic transformation proceeds in five stages. In general, at completion of martensitic transformation the temperature is much lower for the hydrogen-treated steel than for the untreated material, the greatest difference (180° C. compared with 260° C.) being obtained with cooling rate *C* (*see* Figs. 3*a* and *b*).

With the highest cooling rates (*A* and *B*) only martensitic transformation takes place with the hydrogen-treated steel. With all the lower cooling rates (*C*, *D*, *E*, and *F*) both intermediate and martensitic transformation occur. There is little difference between the intermediate transformation temperature for the hydrogen-treated and untreated steels, with cooling rates *C* and *D*. With the lowest cooling rates (*E* and *F*) this transformation started about 30° C. above and finished about 20° C. below the temperatures obtained in equivalent tests on untreated steel.

The relationships between amount of martensite and cooling time and hardness and cooling time are shown in Fig. 4. It was necessary to measure cooling time instead of cooling rate, in order to relate the results of this work with available isothermal transformation data.[6] The cooling time from 870° to 300° C. (*S*, sec.) was taken as a measure of the severity of quench, instead of the rate of cooling at 300° C. (*R*, ° C./sec.) which was used in previous work on weldability.[4, 5] For a welded joint, cooling time *S* can be related to cooling rate *R* by the equation $R = K/S$, where *K* depends upon the available heat sink. In normal metal-arc welding practice, *K* varies from about 200 to 140, decreasing as the heat sink becomes more restricted.

The values of temperature have been obtained from idealized cooling curves from which transformation ' kinks ' have been removed, to facilitate comparison of these results with future work on other steels, where such kinks may occur at other temperatures.

The results shown in Fig. 4 indicate that, for a given cooling time, hydrogen treatment has little effect on the final hardness of the steel. Although

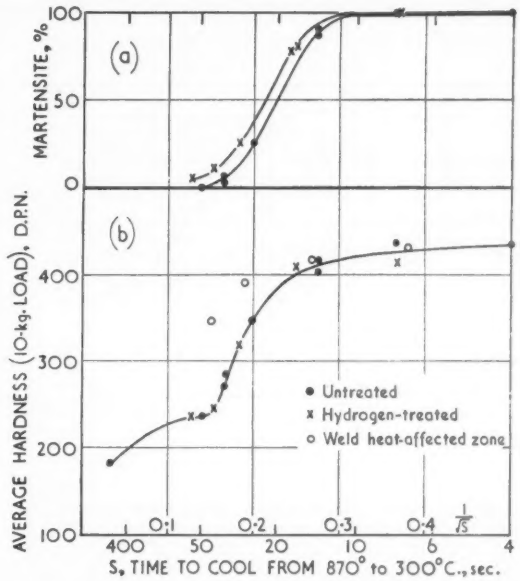


Fig. 4—Relationship between cooling time and (*a*) transformation product, (*b*) hardness, for Mn–Mo steel

the presence of hydrogen appears to increase the amount of martensite formed with a given cooling rate, this effect is not reflected in higher hardness values.

The greater amount of martensite in the hydrogen-treated steel would be expected to result in higher hardness values for this steel than for the untreated steel. It will be seen from Fig. 4 that the amount of martensite* in the hydrogen-treated steel is greater than that in the untreated steel by an almost constant amount. This constant amount of transformation represents about 7–10% of the whole transformation occurring during cooling, and may be that which occurs in ' bursts ' after the main transformation. Some bursts of delayed transformation occur with the untreated steel, but these are much fewer than those occurring with the hydrogen-treated steel.

The ' burst ' phenomenon in the martensitic transformation has been observed by Machlin and Cohen,[12] and was attributed to internal strain affecting the nucleation process. This strain may be built up by the excess hydrogen forced out of solution during the formation of martensite, as both the diffusion rate and solubility of hydrogen in martensite are very low.[13]

The delayed bursts may represent the transformation of austenite containing a large amount of hydrogen into a high-hydrogen martensite, since it is possible that hydrogen, being also an interstitial element in iron, will act in a similar manner to carbon in respect of the depression of M_s. If it is assumed that the steel immediately before transformation to martensite contains 12 ml. of hydrogen per 100 g. of steel, and that atoms of carbon and hydrogen have equal effects on the depression of M_s, then according

* These ' bursts ' of transformation were reproducible in duplicate tests and were not attributed to sticking of the dial gauge, as the instrument was continually vibrated during tests and the scale was set to a different zero for each test.

* Determined by dilatation only.

Table IV

EFFECT OF HEATING CONDITIONS AND DEGASSING ON THE SUBSEQUENT TRANSFORMATION OF A MANGANESE–MOLYBDENUM STEEL

Steel Condition	Peak Temp., °C.	Austenitizing Time, sec.	Time to Cool, 870–500° C., sec.	Intermediate Transformation		Martensitic Transformation			Hardness Using 10-kg. Load, D.P.N.
				50% Trans., °C.	Relative Amount,* %	Arrest Temp., °C.	Finish Temp., °C.	Relative Amount,* %	
As-received	1230	5·3	4·5	425	10	290	260	90	403
,,	1225	8·5	4·5	425	12	290	255	88	415
,,	1230	22·8	4·8	445	50 (44)	305	270	50 (56)	363
,,	1345	6·6	4·5	425	14	293	242	86	424
,,	1030	2·9	4·5	465	50	310	270	50	379
Degassed	1220	5·4	4·6	445	20 (18)	...	263	80 (82)	413

* Figures in brackets are corrected for variation in cooling time

to the formula of Payson and Savage[14] a depression of M_s by about 5° C. would be expected. This difference is not detectable in the transformation diagrams for the untreated and hydrogen-treated steel, because the limit of accuracy in the experimental determinations of M_s is about $\pm$ 5° C.

After martensite has started to form in the hydrogen-treated steel, it is probable that the hydrogen concentration in the remaining austenite is increased proportionately. This theory is in agreement with present knowledge on the solubility of hydrogen, which is much lower in martensite than in any other transformation product.[13] In addition, since the diffusibility of hydrogen is very low in martensite, the hydrogen remaining in the small islands of austenite towards the completion of transformation may be unable to diffuse out of the steel. Thus a high concentration of hydrogen may be built up in the remaining austenite towards the finish of transformation. This concentration may be enough to depress M_s sufficiently to arrest the transformation. For this theory to be effective a depression of M_s by over 100° C. must be accounted for. This would mean that, if the hydrogen atom has the same effect as the carbon atom in this respect, the hydrogen concentration in the remaining austenite would be increased by a factor of at least 25, which is rather unlikely. It is possible, however, that hydrogen may have a somewhat greater effect than carbon on the depression of M_s, which would make the theory more tenable, but its effect cannot be much greater or it would be detected at the start of transformation.

If this theory is correct, the product of the bursts of transformation depends for its properties upon the presence of high local concentrations of hydrogen. It is probable that this hydrogen will diffuse away over a period of time, and this might lead to some reduction in hardness. This may account for the similar hardness of both untreated and hydrogen-treated specimens which have had the same thermal treatment, as the hardness tests were made some weeks after the dilatation tests.

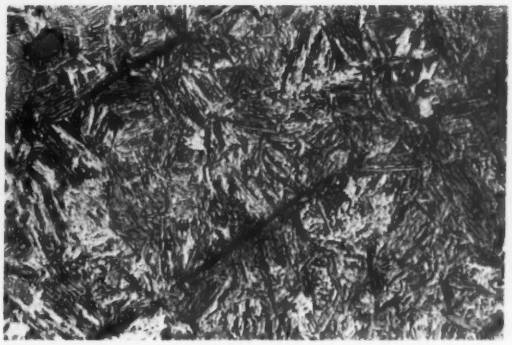
The increase in amount of martensitic transformation product in the hydrogen-treated specimen compared with the untreated specimen roughly corresponds to the increase in amount of delayed transformation that occurs, in bursts, after the main martensitic transformation. As the product of this delayed transformation does not eventually have the hardness of martensite, it could be argued that the product was not martensite at any time. According to Ko[15] it may be possible for the intermediate transformation (bainite) to occur below the M_s temperature and to be initiated by the martensite transformation. This theory, also, could account for the similar hardness values observed for both untreated and hydrogen-treated specimens.

Another interesting feature illustrated in Fig. 4 is the difference between actual heat-affected-zone hardness values and hardness values for the dilatation specimens. With the higher cooling rates, when the structure consists mainly of martensite, there is little difference in hardness, but with lower rates the hardness of the dilatation specimens is less than that of the corresponding weld heat-affected zone. This may be because the shrinkage stresses imposed during the cooling of actual welds tend to strain-harden the heat-affected zone. In this connection, it is unlikely that martensite would be stressed sufficiently to cause any marked hardening, but it is possible that the weaker intermediate structure could be hardened in this way, which would be consistent with the results obtained.

It is also probable that the peak temperature to which the dilatation specimens were heated has some bearing on the difference in hardness. It can be seen from Table IV that increasing the peak temperature from about 1230° to 1345° C., using cooling rate *C*, increased the hardness from 409 D.P.N. to 424 D.P.N. This increase was observed with a mainly martensitic structure, and greater increases may be possible where there is less martensite present. Note also that the hardness values for the actual heat-affected zones were taken in the region of maximum hardness, *i.e.*, close to the fusion line, where high peak temperatures were reached.

The effect of stress on the transformation of austenite could also be considered in relation to the difference in hardness between actual and simulated heat-affected zones. However, previous work[16] has shown that the presence of a tensile stress during the transformation of austenite in a high-nickel steel tends

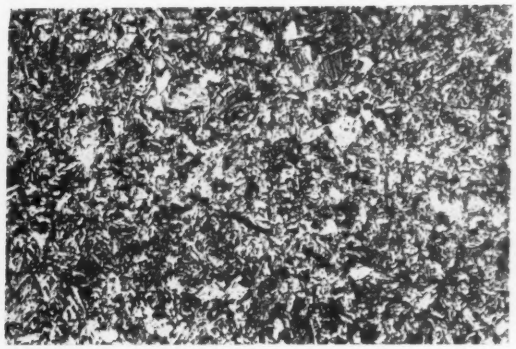
(a) Inclusions enlarged



(b) Inclusions unaffected

Fig. 5—Photomicrographs of Mn–Mo steel: (*a*) Hydrogen-treated, peak temperature 1230° C., cooling rate *A*; (*b*) untreated, peak temperature 1246° C., cooling rate *A*

(a) Fairly coarse structure



(b) Fine-grained structure

(c) Coarse-grained structure

Fig. 6—Photomicrographs of Mn-Mo steel: (*a*) Untreated, peak temperature 1225° C., austenitizing time 8·5 sec., cooling rate *C*; (*b*) untreated, peak temperature 1030° C., austenitizing time 2·9 sec., cooling rate *C*; (*c*) untreated peak temperature 1345° C., austenitizing time 6·6 sec., cooling rate *C*

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to promote transformation. If this result holds for the Mn–Mo steel, it would have the reverse effect on hardness to that observed in the present experiments. It is probable, therefore, that in this instance the effect of stress on transformation is slight and the small change in transformation produced has little effect on hardness.

The dilatation treatment given to the hydrogen-treated specimens enlarged most of the stringer (silicate) type of inclusions. The enlargement of one of these inclusions and the initiation of cracks at its ends, in a specimen cooled at rate *A*, is shown in Fig. 5*a*. (Some of the inclusions were enlarged to a much greater extent than that shown.) A comparable photomicrograph for the untreated steel cooled at the same rate is shown in Fig. 5*b*, and in this instance none of the inclusions is enlarged. This effect of hydrogen occurred with almost every stringer type of inclusion, but no effect was observed on more globular types of inclusion, *e.g.*, manganese sulphide.

Effect of Peak Temperature, Austenitizing Time, and Degassing on Subsequent Transformation

The results of the various dilatation tests made using cooling rate *C* are given in Table IV. The tests, with one exception, were made on untreated Mn–Mo steel.

The specimen, heated to the normal peak temperature of about 1230° C. at a rather lower heating rate than in the standard test, gave the same transformation on cooling (80% martensite) as that observed in the standard test. The structure produced is shown in Fig. 6*a*, the austenitizing time being 8·5 sec. compared with 5·3 sec. for the standard test. This slightly longer time, which had no effect on subsequent transformation, was similar to that obtained in the standard test on hydrogen-treated material.

Increasing the austenitizing time to 22·8 sec., however, reduced the amount of martensite produced to about 50%, and raised the temperatures for the start of intermediate transformation and the finish of martensitic transformation. The same transformation effects during cooling were observed in a test where the peak temperature was reduced from 1230° to 1030° C. (austenitizing time 2·9 sec.), but in this case the structure was fine-grained (Fig. 6*b*).

Increasing the peak temperature from 1230° to 1345° C. had little effect on the amount of martensitic transformation, but lowered the temperature for completion of martensitic transformation from 260° to 242° C. and increased the hardness slightly. This structure is shown in Fig. 6*c*; the grain size was increased (*cf.* Fig. 6*a*).

These results show that for a given cooling rate the peak temperature to which the specimen is heated affects the temperature for completion of martensitic transformation during cooling; the higher the peak temperature, the lower the end-of-transformation temperature. Increasing the austenitizing time raises the temperatures both for start of intermediate transformation and completion of martensitic transformation. In addition, austenitizing time affects the transformation product when the cooling rate is such that both intermediate and martensitic products are formed; a considerably longer austenitizing time than

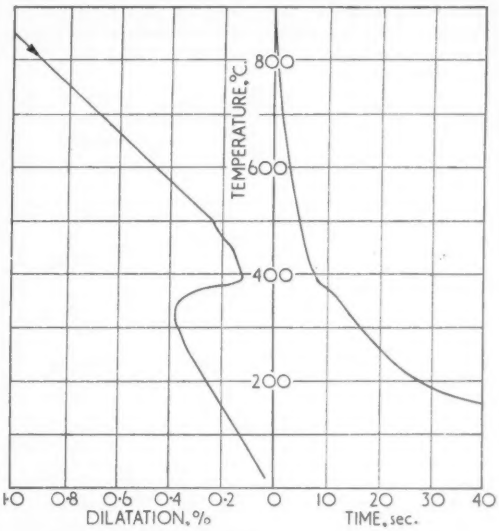


Fig. 7—Dilatation and cooling curves for a degassed Mn–Mo steel, using cooling rate *C*. (Peak temperature 1220° C.)

the standard gives much more intermediate transformation. This result shows that the rapid heating conditions used in these experiments were necessary to obtain a true estimate of the transformation occurring in the zones adjacent to welds on alloy steel. This factor was overlooked in the investigations of Christenson, Nelson, and Jackson[17] and Hoyt, Sims, and Banta.[18]

The foregoing results indicate that the heating conditions chosen for the standard test, combined with cooling rate *C*, gave the maximum amount of martensitic transformation for that cooling rate, but the temperature for completion of martensitic transformation would have been lower if the peak temperature had been higher.

All the results previously described in this section have related to dilatation tests made on untreated steel, and in each test there was a pause in the martensitic transformation. This pause commenced between 290° and 310° C., depending on the heating conditions, and lasted while the temperature fell by about 20° C. (*see* Fig. 3*a*). In the test on the hydrogen-treated specimen mentioned earlier (p. 277) there was more than one pause in transformation (*see* Fig. 3*b*). However, the test in which a degassed specimen was heated to the standard peak temperature and cooled at rate *C* showed no pause in the martensitic transformation (Fig. 7). Thus the removal of residual gas (0·2 ml. of hydrogen per 100 g. of steel, *see* Table I) removed the pause, and the addition of hydrogen was accompanied by the appearance of a number of pauses, a result which confirms that the martensitic transformation is impeded by hydrogen in the steel.

Continuous-Cooling Transformation Data in Relation to Isothermal Transformation Data

A comparison between continuous-cooling and isothermal transformation data is made in Fig. 2*a*. The isothermal transformation diagram shown is for

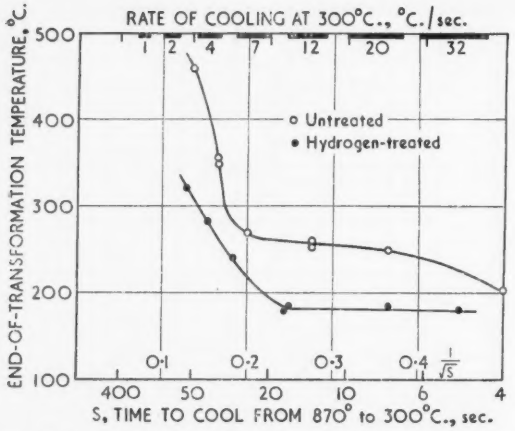


Fig. 8—Relationship between end-of-transformation temperature and cooling time for Mn–Mo steel

steel En 13 and was produced by a committee of the British Iron and Steel Research Association.[6] The analysis of the En 13 steel used to prepare this diagram is given in Table I; it is similar to that of the Mn–Mo steel except for the nickel content.

No isothermal data are given in Fig. 2*a* for temperatures below the start of martensitic transformation, since this information is not available from the isothermal transformation diagram. In the C.C. transformation diagram the progress of intermediate and martensitic transformation is plotted separately. The effect of the increased nickel content in steel En 13 compared with the Mn–Mo steel would be to depress the isothermal diagram as a whole (*i.e.*, lower temperature) and move it to the right (longer time), although this effect would be slight because the difference in nickel content is only small.

It has been stated by Grange and Kiefer[7] that an approximation to the C.C. transformation diagram can be derived from the appropriate isothermal diagram. However, this derivation is restricted to temperatures above M_s and, in addition, these results indicate that it is mainly restricted to lower cooling rates than those found in welding.

In the method used by Grange and Kiefer the C.C. diagram always lies below (lower temperature) and to the right of (longer time) the isothermal diagram. The start of transformation calculated in this way from the isothermal diagram for En 13 steel gives a line approximating to the observed start of transformation of the Mn–Mo steel on continuous-cooling; the progress of transformation, however, cannot be derived in this manner.

There is good agreement between the expected and observed M_s temperatures for the two steels, since the greater alloy content of En 13 steel would be expected to lower the M_s temperature by about 14° C.[14] The calculated M_s temperatures for the Mn–Mo and En 13 steels are 405° and 391° C. respectively. These values are in good agreement with the results quoted here and elsewhere,[6] *i.e.*, 400° and 385° C. respectively.

It appears, therefore, that there is a reasonable chance of predicting the start of transformation, on continuous cooling at welding rates, from the isothermal diagram. However, little information can be obtained on the subsequent progress of the intermediate transformation, and no information is available on the all-important martensitic transformation.

TRANSFORMATION DATA IN RELATION TO WELDABILITY

In the earlier tests,[1] where welds were made with a B.S.1719 class E217 electrode, a critical temperature of 290° C. was observed for the finish of transformation in alloy steel during continuous cooling. To compare the earlier results with those for the Mn–Mo steel, the end-of-transformation temperature for the untreated steel is plotted against $1/\sqrt{S}$ (Fig. 8). The values of S are again obtained from idealized cooling curves, from which the transformation 'kinks' have been smoothed out.

In cracking tests reported in a previous paper,[5] the Mn–Mo steel was welded with a class E217 (rutile-coated) electrode. Slight cracking was observed with a cooling time (870–300° C.) of 28 sec. and no cracking with a cooling time of 44 sec.; these cooling times correspond to end-of-transformation temperatures of 277° and 350° C. respectively (*see* Fig. 8). This result agrees with the earlier work[1] since in this case, also, an end-of-transformation temperature in the region of 290° C. will be critical with respect to hard-zone crack initiation.

It should therefore be possible to deduce the liability of an alloy steel to give hard-zone cracks when welded with a class E217 electrode from its end-of-transformation diagram (as in Fig. 8). When more data have been obtained on welding a number of alloy steels with class 6 (low-hydrogen) electrodes, it may be possible to predict from the appropriate diagram the liability to hard-zone cracking when welding a given steel with this type of electrode. A few tests made on the Mn–Mo steel with a class E614 electrode have shown that the critical cooling time (870–300° C.) is between 3·5 and 6·8 sec.;[5] these two cooling times give end-of-transformation temperatures of approximately 200° and 250° C. respectively. Therefore, if a critical end-of-transformation temperature exists for alloy steels when welded with low-hydrogen electrodes, this temperature is likely to be within the range 200–250° C.

Probable critical end-of-transformation temperatures when using different types of electrode are given in Table V. However, except for the class E217 electrode, these results are at present restricted to the Mn–Mo steel.

The end-of-transformation temperatures that have been compared with weldability test results are not necessarily the actual temperatures at which transformation ends during welding. This is due to the presence of different amounts of hydrogen in the heat-affected zone, depending on the type of welding electrode used. Some typical values[11] for diffusible hydrogen evolved at room temperature are included in Table V.

It is reasonable to suppose that the concentration of hydrogen in the heat-affected zone would be rather lower than the values quoted in Table V. Even though the diffusion of hydrogen through steel is

Table V

SEVERITY OF HARD-ZONE CRACKING RELATED TO END-OF-TRANSFORMATION TEMPERATURE

Electrode Type		Cooling Time, 870–300° C., sec.			Probable Critical Temp. for End-of-Transformation, ° C.	Hydrogen Evolved Under Paraffin at Room Temperature from Typical Welds, ml./100 g. of fused metal*
B.S. 1719 Class	Coating	Severe Cracks	Slight Cracks	No Cracks		
E111P	Cellulosic	25	...	56	> 300	27
E217	Rutile	14	25	44	290	15
E317	Rutile-basic	14	...	28	260–280	14
R456	Oxide-silicate	28	...	44	> 300	20
E537	Oxidizing	...	...	7·3	< 250	4·4
E614	Low-hydrogen (basic)	...	3·5	6·9	200–250	2·1
Austenite 18/8	Rutile	...	...	4·1	< 200	0

* Values corrected for loss due to solution of hydrogen in paraffin

rapid at high temperatures, there is probably still a gradient in hydrogen concentration at these temperatures. This would result in a lower hydrogen concentration in the heat-affected zone than in the fused zone. This effect may, however, be counteracted by the fact that the fused zone transforms while the heat-affected zone is still austenitic, because of the difference in alloy content.

The effect of this earlier transformation of the fused zone would be to force additional hydrogen into the heat-affected zone, since during the transformation of austenite the solubility of hydrogen in steel is considerably lowered. The effects of austenite transformation on hydrogen solubility, and of alloy content on transformation, which led to the previous conclusion are well illustrated in Fig. 5 of a paper by Andrew, Lee, and Quarrell.[19]

The hydrogen-treated specimens used in the dilatation tests contained about 12 ml. of diffusible hydrogen per 100 g. of steel, and it is probable that the high initial heating rate used in the dilatation tests did not allow time for much of this hydrogen to diffuse out of the steel during heating. At the higher temperatures there would be less tendency for the hydrogen to diffuse out of the steel, owing to the increased solubility and relatively low diffusibility. For this reason it can be assumed that the dilatation tests on the hydrogen-treated Mn–Mo steel gave a fair approximation to the conditions obtained in the heat-affected zone when welding this steel with class E317 electrode. Therefore, the curve shown in Fig. 8 for the hydrogen-treated steel probably gives the actual end-of-transformation temperature for this steel, when it is welded with a class E317 electrode. If this is true, the onset of hard-zone cracking, which is known to occur below 100° C. in this type of steel, is related to the occurrence of the low end-of-transformation temperature of 180° C.

The end-of-transformation/cooling-time curves for the Mn–Mo steel welded with the higher-hydrogen electrodes (class E111 P, E217, and R456) should lie nearer to the origin in Fig. 8 than the curve for the hydrogen-treated steel. The curve relating to the low-hydrogen electrode should lie between the two curves, probably nearer to the curve for the untreated steel. The curve for an austenitic electrode should be similar to that for the untreated steel.

In view of these results there are probably two criteria for relating transformation characteristics to weldability:

(i) End-of-transformation temperature for the untreated steel

(ii) End-of-transformation temperature for the steel containing a given amount of hydrogen, equivalent to that produced in the heat-affected zone of welds made with the electrode under consideration.

The first method is the more simple experimentally, but different critical temperatures will be observed for any given steel, depending on the type of electrode used for welding. The second method will give a definite critical temperature for each steel, irrespective of the electrode used for welding, but the experimental work necessary to derive this temperature would be both difficult and extensive. If the first method proves to be satisfactory with other steels, it should be the more suitable method for examining the liability of a steel to hard-zone cracking.

The results of dilatation tests made using different peak temperatures and a fixed cooling rate showed that the higher the peak temperature the lower the temperature at which transformation was completed. This fact, in conjunction with the previous results, indicates that the region of the heat-affected zone closest to the fusion line should be most prone to cracking. This does not always appear to be true in practice, for cracks have been observed in parts of the heat-affected zone which have not reached a temperature greater than 1100° C. during the welding process. Pure micro-cracking, however, which can occur when welding an alloy steel with higher-hydrogen electrodes, is usually found near the fusion line, where the heat-affected zone has been heated to peak temperatures above 1300° C.

The type of crack that is enlarged by external restraint in a welded joint usually occurs further from the fusion line, in that part of the heat-affected zone which is more rigid and in a more severe state of stress than that adjacent to the relatively soft weld bead, which can deform more easily to accommodate major stresses. It is therefore suggested that the position of pure micro-cracks is governed by the steel structure and the resulting micro-stresses, whereas the position of major fissures is governed by a combination of micro-stresses and the overall macro-stress pattern.

A comparison of hardness values from the dilatation tests with those from the welding tests described in a previous report[5] is made in Fig. 4. These values are in good agreement when the structure is fully martensitic. When less martensite is present, however, lower hardness values are obtained in the dilatation specimen than in the weld heat-affected zone. A possible reason for this effect is that the hardness values obtained from the welding tests are for that part of the heat-affected zone nearest to the fusion line where high peak temperatures have been reached, so that a higher hardness would be expected (*see* Table IV).

An interesting effect which emerges from this and previous work[1] concerns the significant relationship observed between end-of-transformation temperature during cooling and incidence of hard-zone cracking when steels are welded with a rutile-coated electrode. All the results obtained have indicated that this relationship holds when the steel composition and the cooling rate are varied. The relationship may apply when different welding electrodes are used, but each electrode is likely to give a different critical temperature for completion of transformation. This temperature is likely to depend on the diffusible hydrogen content of the weld metal produced, and is likely to be lower with small hydrogen contents.

The effect of hydrogen is now recognized by electrode manufacturers and has led to the production of low-hydrogen electrodes which are most desirable for welding high-tensile steels. If the relationship between incidence of hard-zone cracking and temperature for completion of transformation is established, steelmakers will have a guide to the design of more weldable steels. In this connection, it is also probable that the production of low-hydrogen steels would be a worthwhile aim.

CONCLUSIONS

The existence of the critical temperature of 290° C. for end-of-transformation[1] has been shown to apply for a commercial low-carbon Mn–Mo steel welded with B.S.1719 class E217 electrodes. In this steel the critical temperature depends upon the type of electrode used. The lower the potential hydrogen content of the electrode, the lower is the critical temperature.

Results from rapid dilatation tests on the Mn–Mo steel have shown that the transformation to martensite becomes more sluggish as it proceeds; there is a pause in the transformation, which is then completed at a lower temperature. When the steel is supersaturated with hydrogen immediately before the dilatation test, there are more pauses in the transformation to martensite and the temperature for completion of transformation is lowered considerably for a given cooling rate. When the steel is degassed before tests there are no pauses in the transformation. Supersaturation of the steel with hydrogen does not have any measurable effect upon the M_s temperature.

Heating the Mn–Mo steel to higher peak temperatures in the rapid dilatation tests lowers the temperature for completion of transformation with a given cooling rate. The austenitizing time affects both the transformation product and the temperature for completion of transformation.

The rate of cooling from a given peak temperature affects the temperature for the start of intermediate transformation of the Mn–Mo steel, but has little effect on the M_s temperature. The temperature for completion of transformation is also affected by cooling rate.

The results show that it should be possible to predict the start of transformation of alloy steels during continuous cooling at welding rates from the isothermal data, but little information can be gained regarding the subsequent progress of transformation.

Acknowledgments

The author wishes to express his appreciation of the valuable discussions on the work given by members of the FM.8 Committee of the British Welding Research Association.

The helpful criticism of the work given by Dr. T. Ko, Dr. K. Winterton, and Mr. B. J. Bradstreet is also gratefully acknowledged.

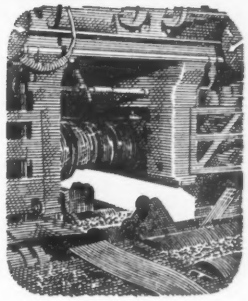
Thanks are due to the United Steel Co's., Ltd., and to Mr. E. J. Millett, for carrying out analyses for total hydrogen by vacuum-heating.

References

1. C. L. M. Cottrell: *J. Iron Steel Inst.*, 1953, vol. 174, pp. 17–24.
2. H. F. Tremlett: *Welding Metal Fab.*, 1951, vol. 19, pp. 224–228, 259–264.
3. C. E. Sims and H. M. Banta: *Welding J.*, 1949, vol. 28, pp. 178s–192s.
4. C. L. M. Cottrell, M. D. Jackson, and J. G. Whitman: *Welding Res.*, 1951, vol. 5, Aug., pp. 201r–215r.
5. C. L. M. Cottrell, M. D. Jackson, and J. G. Purchas: *Ibid.*, 1952, vol. 6, June, pp. 50r–57r.
6. "Atlas of Isothermal Transformation Diagrams of B.S. En Steels." Spec. Rep. No. 40: 1949, London, The Iron and Steel Institute.
7. R. A. Grange and J. M. Kiefer: *Trans. Amer. Soc. Metals*, 1941, vol. 29, pp. 85–116.
8. J. A. Wheeler and V. Kondic: Symposium on Metallurgy of Steel Welding, pp. 71–83: 1946, London, British Welding Research Association.
9. G. L. Hopkin: *Trans. Inst. Weld.*, 1944, vol. 7, pp. 76–78.
10. M. W. Mallett and P. J. Rieppel: *Welding J.*, 1950, vol. 29, pp. 343s–347s.
11. K. Winterton and C. L. M. Cottrell: *Metallurgia*, 1954, vol. 49, pp. 3–7.
12. E. S. Machlin and M. Cohen: *Trans. Amer. Inst. Min. Met. Eng.*, 1951, vol. 191, pp. 746–754; *J. Met.*, 1951, vol. 3, Sept.
13. S. S. Nosyreva: *Zavodskaya Laboratoriya*, 1948, vol. 14, No. 3, pp. 307–310.
14. P. Payson and C. H. Savage: *Trans. Amer. Soc. Metals*, 1944, vol. 33, pp. 261–275.
15. T. Ko: Private communication.
16. A. H. Cottrell: *J. Iron Steel Inst.*, 1945, No. 1, pp. 93p–104p.
17. A. L. Christenson, E. C. Nelson, and C. E. Jackson: *Trans. Amer. Inst. Min. Met. Eng.*, 1945, vol. 162, pp. 606–626.
18. S. L. Hoyt, S. E. Sims, and H. M. Banta: *Ibid.*, pp. 326–349.
19. J. H. Andrew, H. Lee, and A. G. Quarrell: *J. Iron Steel Inst.*, 1942, No. II, pp. 181p–192p.

IRON AND STEELWORKS ENGINEERING

THE IRON AND STEEL ENGINEERS GROUP



Modern Industrial Boiler Plant

By W. P. C. Ungoed

SYNOPSIS

The need for a modernization of industrial plant is illustrated in the paper. The planning of a boiler extension is described, together with typical works requirements for process steam and power. The advantages of back-pressure generation are illustrated. The salient points of modern boiler design are described, and, as industrial boiler plant is required to operate with a minimum of down time, emphasis is laid on the points of design which tend to increase availability. The descriptions of various firing methods and designs also stress efficiency and availability. 890

It is the aim of the paper to present some guide to the choice and operation of modern industrial boiler plant, together with the problems associated with higher efficiencies.

The change in economic conditions, particularly since the war, and the impetus resulting from the various productivity reports have had great influence on the design of steam-raising equipment. The replacement of old inefficient plant by modern designs will certainly be one of the aims of the National Industrial Fuel Efficiency Service in the interest of national thermal economy; as an indication of the overall task, summaries of boiler plant now in service are given in Table I. The Table contains an analysis of 5% of the total number of industrial establishments taken at random from the survey of the potentialities of back-pressure generation carried out by the Ministry of Fuel and Power. Some variations from the figures quoted will be revealed with the publication of the full summary, and so the Table only gives an approximate indication of the present boiler-plant position.

These figures reveal that a high proportion of industrial steam in the U.K. is raised from small boiler units 30–50 years old. Much of this plant must be operating at low thermal efficiencies, and insufficient work is being done by the steam outputs at the low steam pressures.

Manuscript received 22nd December, 1953.

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In the inter-war years, low fuel prices and lack of capital did not encourage the modernizing of such plant, but present-day conditions are entirely different. Fuel and operating costs have risen so much that it is now necessary to investigate all thermal economy schemes for industry to remain competitive in the face of increasing international competition.

This urgent change to high-efficiency plants may present some difficulty to engineers unacquainted with the necessary techniques, but the main requirements of any projected or new installations are:

(1) High availability
(2) Minimum operational and maintenance costs
(3) High overall efficiency.

In addition to these main requirements, the plant should also be designed to cover the following items:

(i) To be capable of consuming all the waste solid, liquid, and gaseous fuels arising within the industry
(ii) To meet the variation in process steam demand
(iii) To be combined with suitable economic schemes of back-pressure or pass-out generation
(iv) To be arranged for independent firing by a bunker fuel, if the fuels in (i) cannot be stored.

The Sankey diagram (Fig. 1) shows the normal site demands for process steam, power, and cold blast. These requirements are being met by the waste fuels and heat available on site, the bought fuels being required to cover temporary reductions in blast-furnace gas availability.

MODERN BOILER DESIGN

The variety of boiler designs available today prove on examination to have the following features in common.

Reduction in Boiler Size

Research in heat-transmission problems has enabled the boiler designer to reduce the heating surface required for boiler outputs by increasing the heat-transfer rates in the various sections. In the combustion chamber, this has been brought about by the greater use of close-pitched bare-tube water walls

suitably disposed to absorb the maximum of radiant heat. Refractory areas, where necessary to maintain auto-ignition, are kept to a minimum, and the present method of applying plastic refractory to studded side and front wall tubes allows easy alteration to the area required.

Other reductions in boiler size are made possible by the higher rate of heat transfer obtained by increasing the rate of flue-gas flow. The curves in Figs. 2*a* and *b* show the gain in convection coefficient made possible by the adoption of small-diameter boiler tubes, coupled with high gas velocities.

This progressive gain in heat transfer is limited by abrasion of the boiler tubes by grits entrained in the flue gas. Improvements in combustion methods resulting in lower fly ash allow further heating-surface economies to be made.

A further reduction in tube surface area can be obtained by the increase in water velocity inside the boiler tubes (Fig. 3) and has led to the number of forced-circulation boilers now in use. This type was originally intended for pressures of 1250 lb./sq. in. gauge and over, because at these high pressures the density of steam and water approach so closely that it is difficult to obtain sufficient hydraulic head for natural circulation. The advantages in the reduction of the boiler heating surface have been such that this type of boiler is popular at all working pressures.

The preceding design changes have resulted in the hitherto uneconomical bank of boiler convection tubes being greatly reduced or dispensed with completely. The duty of the economizer is correspondingly increased, and it is now quite common to find an inlet gas temperature of 1400° F., and 10% of

Table I

DISTRIBUTION OF BOILERS IN USE AT 207 INDUSTRIAL AND NON-INDUSTRIAL ESTABLISHMENTS*

(*a*) Distribution According to Age and Size

Normal Rate of Steam Production in Winter, 1000 lb./hr.	Age of Boilers, years						
	Under 5	5–9	10–19	20–29	30–49	50 and Over	All Ages
Under 2·5	10	3	19	14	18	5	69
2·5–4·9	5	8	27	30	47	17	134
5·0–9·9	26	18	92	53	169	50	408
10·0–19·9	9	7	39	14	41	5	115
20·0–39·9	7	3	12	11	...	...	33
40·0 and over	11	4	3	5	...	...	23
All sizes	68	43	192	127	275	77	782

(*b*) Distribution According to Age and Maximum Permissible Working Pressure

Maximum Permissible Working Pressure, lb./sq. in. gauge	Age of Boilers, years						
	Under 5	5–9	10–19	20–29	30–39	50 and Over	All Ages
Under 100	13	5	35	18	33	22	126
100–149	11	16	80	36	92	31	266
150–199	20	5	43	36	127	23	254
200 and over	24	17	34	37	23	1	136
All pressures	68	43	192	127	275	77	782

(*c*) Distribution According to Size and Pressure

Maximum Permissible Working Pressure, lb./sq. in. gauge	Normal Rate of Steam Production in Winter, 1000 lb./hr.						
	Under 5	2·5–4·9	5·0–9·9	10·0–19·9	20·0–39·9	40 and Over	All Sizes
Under 100	30	32	57	7	...	...	126
100–149	25	68	124	49	...	...	266
150–199	10	27	173	33	4	7	254
200 and over	4	7	54	26	29	16	136
All pressures	69	134	408	115	33	23	782

* This represents a sample of about 5% of such establishments using at least 2000 tons of coal, or the equivalent in coal, coke, and oil, annually (but not necessarily entirely for steam raising).

the total evaporation of the unit raised in this section.

Reduction in Boiler Weights for Given Outputs—Attention has also been given to the question of reducing the steel quantities needed for given outputs. Apart from the economies described in the preceding section, efforts have been made to reduce the number of boiler drums required to a minimum. The present-day three-drum boiler is regarded as a straightforward convectional design, capable of maintaining high steam purities over a wide range of conditions. The 'two-and-one' drum designs are satisfactory as regards water distribution, but they are only able to maintain the required steam purity with a narrowing set of boiler-water concentrations and load conditions.

Further reductions are possible in the boiler steel structure by using one of the designs in which the bottom drum rests on a stool foundation, the top drum being supported within guides by the boiler tubes.

Attention has again been focused on the drumless 'once-through' type of boiler. This principle of boiler operation at critical pressures fell into disfavour owing to chemical and metallurgical difficulties. Sufficient work has now been carried out on these subjects to justify further interest being taken in this type for high-pressure topping turbo-alternators. It has also been found that this type will operate satisfactorily at sub-critical pressures.

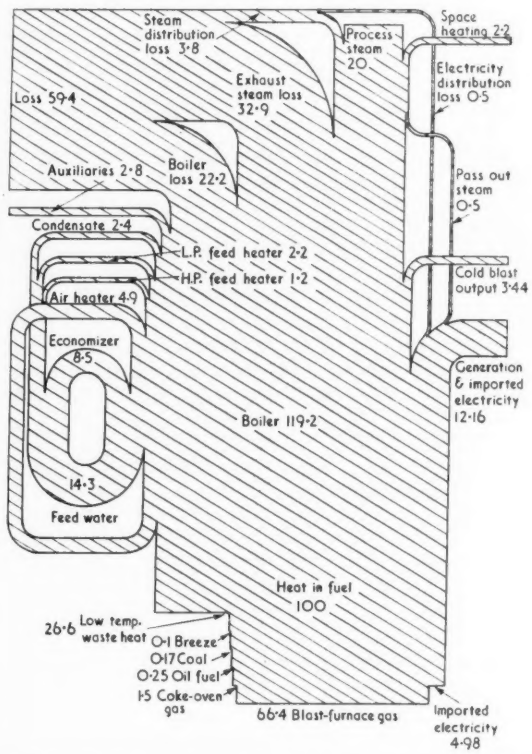

Fig. 1—Sankey diagram of an integrated iron and steel works in operation with a minimum of bought fuel

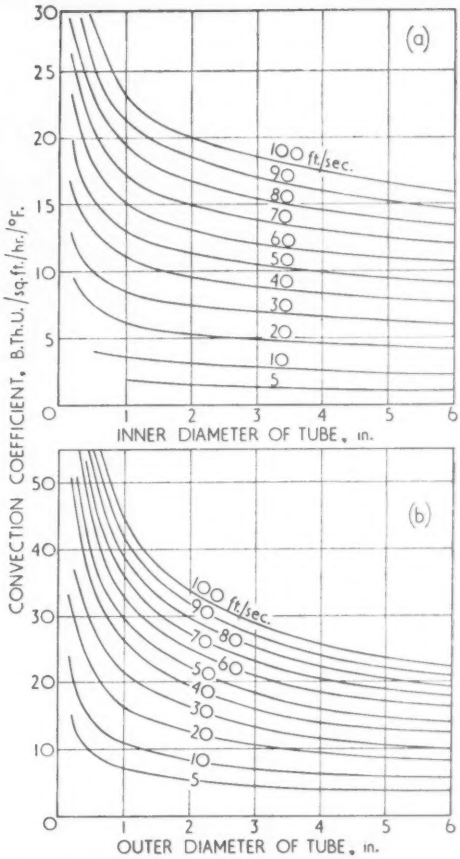

Fig. 2—Coefficients of convection for flow (*a*) through a tube and (*b*) normal to a single tube

The curves in Fig. 4 show the capital and economic advantages to be gained by the adoption of boiler designs based on high rates of heat transfer.

Steam Purity

The reductions in boiler-water surface area, the drum steam content, and the number of drums in

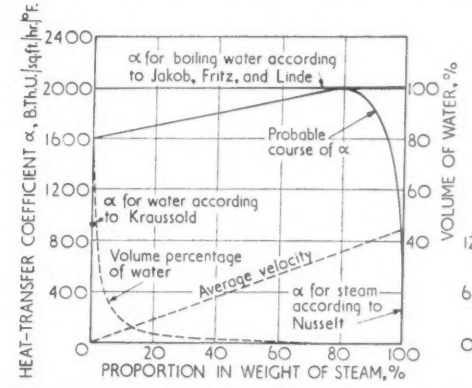
α for boiling water according to Jakob, Fritz, and Linde
Probable course of α
α for water according to Kraussold
Volume percentage of water
Average velocity
α for steam according to Nusselt
HEAT-TRANSFER COEFFICIENT α, B.Th.U./sq.ft./hr./°F.
VOLUME OF WATER, %
AVERAGE VELOCITY, ft./sec.
PROPORTION IN WEIGHT OF STEAM, %

Fig. 3—Heat transmission with a flowing steam–water mixture. Steam pressure 285 lb./sq. in. gauge, internal dia. of tube approx. 1 in.

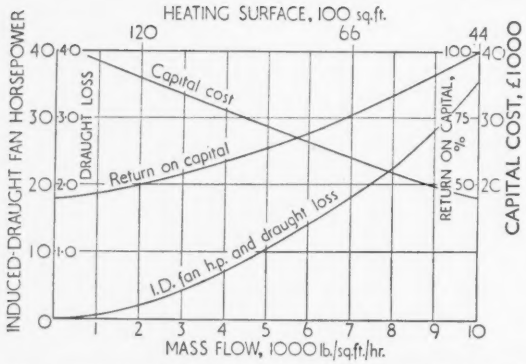

Fig. 4—Relationship between mass flow, coefficient of heat transfer, and capital cost

use have had the effect of bringing into prominence the question of steam purity, as each of these reductions has increased the rate of steam release per sq. ft. of water surface. The additional spray produced has required drying methods and internal equipment capable of dealing effectively with this mixture. Spray removal is more important at 600 lb./sq. in. gauge and over, because at this pressure and temperature the caustic soda in the boiler water is soluble in either water or dry steam, which adds to the problem of superheater deposits and turbine-blade fouling.

Either singly or in combination, the following techniques reduce ' carry-over ':

Two-Drum Method—The steam/water mixture from the boiler generating tubes and side walls is discharged into one drum, from which the steam and water are separated into a main drum, the water particles in the steam coalescing and returning to the boiler water.

Main and Steam Drum—The discharge of all steam and water enters the main drum, and only steam is led to the steam-collecting drum. Suitable drains are incorporated to return the water settling out from the steam.

Baffles and Cyclones—For the final drying, the steam is led through baffles to deflect any water drops back on to the water surface, or through cyclones to effect the same result by centrifugal action.

Measurement of the final steam purity by conductivity is complicated in a boiler–turbine closed cycle by the ammonia remaining in the system, but, after correction, the solid impurities should not exceed one part per million.

Boiler Superheater and Economizer Pressure Parts

The use of modern welding techniques for seal-welding pressure parts has not yet been adopted as fully in the U.K. as in Europe or America. To ensure the least possible interference with continuous operation there is no alternative but to make extensive use of welded steam and water joints.

The introduction of the welded superheater became necessary as the final steam temperatures increased. Above 800° F. the formerly popular ball-and-socket joint becomes unreliable because of creep in the clamping bolt. The use of chromium–molybdenum alloys for the high-temperature zone of the elements is necessary at 875° F. and above. Welding repairs to these alloys are satisfactory, provided that pre-heating and subsequent stress-relieving are carried out to the recommended procedure.

Welded economizers are being introduced for high pressures, but to avoid internal water side inspection and cleaning, which is difficult, feed-water quality must be maintained within narrow limits. For boiler plants on one- or two-shift operation, this type has an advantage over the metal-to-metal clamped joint of being able to withstand the high metal temperatures during flashing without the water wastage otherwise necessary.

Figure 5 indicates the steps in the development of welding for steam mains and the complete abandonment of the stiffening flange. The final example of a butt-welded main with an internal backing ring is suitable for the highest pressures; it is adaptable to site conditions and, by the introduction of the internal ring, prevents damage to the steam-consuming plant by welding beads and scale.

Superheaters and Steam Temperature Control

Superheaters are either horizontal or vertical, and the two types differ in the following respects.

Horizontal Type—Usually referred to as self-draining, it has the great advantage of providing equal protection to each element during flashing by the avoidance of water pockets. It is particularly desirable to use this type for fuels of high calorific value.

Supporting the loops presents some problem, but water-cooled hangers appear to be becoming popular. With heavy fuel oil firing, uncooled supports are liable to vanadium oxide attack with ultimate fracture of the ties.

This superheater arrangement does not usually fit very well into a boiler, and to accommodate it presents some difficulty in the layout of boiler generating tubes.

Vertical or Pendant Type—These fit well into a boiler scheme and can result in close compact units. The elements are self-supporting, and so there is less risk of tube failures from the oxidation of one of the tube ties.

Flashing boilers from cold requires great care so as to dry out every loop, otherwise the metal temperatures of the obstructed elements are liable to exceed

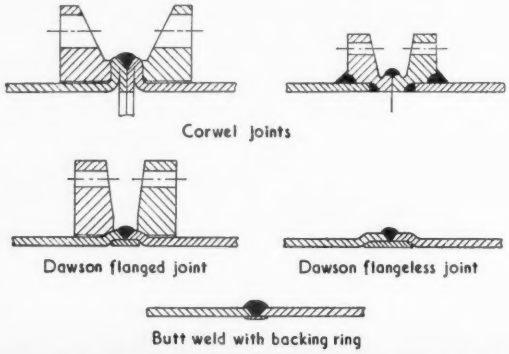

Fig. 5—Developments in steam-main welded joints

the safe limit. For safe operation, an exact flashing programme, with set draught and burner conditions based on experiments with thermocouples at the inlet gas end of chosen elements, is necessary.

Steam Temperature Control—There are a variety of systems in operation for steam temperature control, and preference would be for the system which does not

(i) Add any extensions to the pressure parts of the boiler system
(ii) Depend on either spray or surface desuperheating to the correct temperature.

The reasons for (i) arise from the need to avoid any control system which can be a cause of additional forced stoppages. The objections to desuperheating are the extension to the pressure parts in the case of surface desuperheating and the unnecessary overheating of the steam in the primary superheater.

The working temperature of the metal in the elements is usually so very near the permissible maximum temperature that it leaves very little margin for operational contingencies. To meet these objections, it is preferable to carry out steam temperature control by a combination of a by-pass damper in the cold end of the boiler gas passes together with flue-gas recirculation to maintain the correct temperature at light loads.

Auxiliaries

It is regrettable that pressurized combustion chambers have not been more widely adopted, for the advantages to be gained by this type of combustion coupled with the elimination of induced-draught fans add to the economies in plant size and efficiency.

The layout of this type of system requires forced-draught fans of sufficient capacity and static head to supply the combustion air against the combined

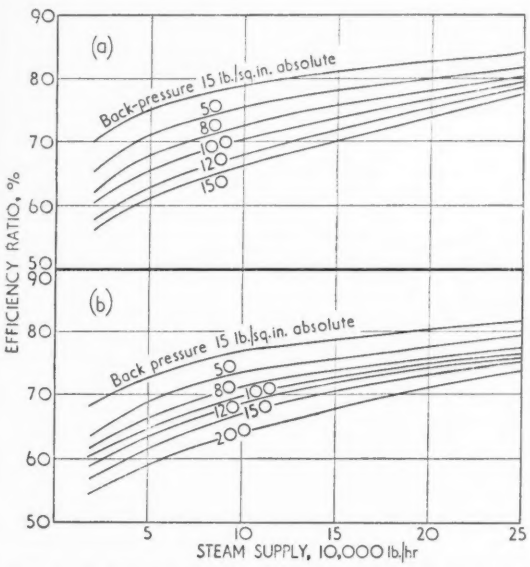

Fig. 6—Relationship between turbine efficiency and back-pressure steam supply. Turbine stop-valve conditions: (*a*) 600 lb./sq. in. gauge, 850° F.; (*b*) 900 lb./sq. in. gauge, 900° F.

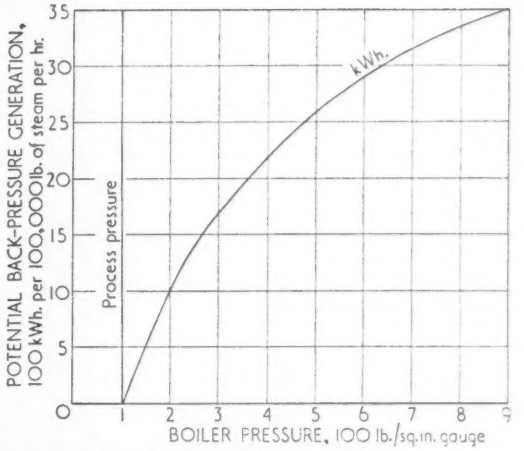
POTENTIAL BACK-PRESSURE GENERATION, 100 kWh. per 100,000 lb. of steam per hr.
Process pressure
kWh.
BOILER PRESSURE, 100 lb./sq.in. gauge

Fig. 7—Relationship between topping pressure and kWh. output on back-pressure generation

system resistance of the air preheaters, together with that of the boiler gas side. The disadvantage of having to provide access and inspection doors to withstand this pressure is not too difficult.

The overall benefits to be gained by adopting this system are a small reduction in combustion chamber volume together with a slight gain in combustion efficiency, owing to better turbulence. Maintenance is considerably reduced, because fewer fans are required, and induced-draught fan-blade cleaning and replacement problems are eliminated. There is also a small reduction in the auxiliaries power consumption, as all the air for combustion is now handled at low temperature and volume. On the bigger boiler units this would account for a gain of about 0·3% in the overall efficiency. It is doubtful whether this principle could be adopted for use with blast-furnace gas, because the prevailing pressure would probably be too low to be effective against the combustion chamber pressure, without the added complication of gas boosters.

In planning so as to employ the minimum of staff, the design, location, and operation of such items as soot blowers need special attention. They are far too often located in ill-ventilated and inaccessible boiler galleries, with the inevitable neglect of their operation. These and similar items should be arranged for remote manual or automatic operation.

For a similar reason, a centralized lubrication system to serve the multitude of grease nipples on damper spindles, soot blowers, rotary seals, and low-speed bearings should be included as an essential part of the plant.

PROCESS STEAM AND BACK-PRESSURE GENERATION

In the installation of new boiler plant, pressure and temperature are often dictated by the existing works system, where the only possible gain in efficiency is in the heat-transfer ratio of the boiler or in its auxiliaries. If the required steam demand can be met by the incorporation of back-pressure or pass-out generation, the gain in overall efficiency is spectacular.

Table II

OPERATING RESULTS OF OIL- AND GAS-FIRED BOILERS

Cause of Stoppage	Duration of Stoppage, days			
	Boiler 1	Boiler 2	Boiler 3	Boiler 4
Annual overhaul and survey	17	15	15	19
Economizer return tube joints	3½	...	4¾	...
Economizer gas side cleaning	4¾	2¾	...	1
Superheater tube replacements	...	...	2	...
Furnace refractories	...	...	6½	...
Fans (electrical and mechanical)	...	...	...	3
High-pressure steam and water joints	3½	3½	2¾	2
Totals	28¾	21¼	31	25

The curves in Fig. 6 show the electrical output possible with back-pressure generation and a steam demand of 100,000 lb./hr. at 100 lb./sq. in. gauge. This gain in combined output with steam pressure does not hold true for turbines with low throughputs: in these sizes, the blade length is so short that steam leakage through the sealing glands and along the blade tips forms too high a proportion of the total (*see* Fig. 7).

Overall efficiencies of 75–80% are achieved in combined boiler back-pressure turbine plants, which compare very well with the 28–30% overall efficiency of a 900 lb./sq. in. gauge 900° F. boiler and condensing turbo-alternator.

HIGH AVAILABILITY

The subject of high plant availability is more important in industry than in central power stations, firstly, because of the higher industrial load factors, and secondly, to avoid the uneconomic investment of capital in standby plant.

Many design features aimed at increasing efficiency and outlined in the section on boiler design are partly experimental. These progressive features always introduce an element of risk to continuous operation, and consideration must be given to how advanced a design can be without impairing availability.

For continuous full duty, an increase of 1% in the overall thermal efficiency of one of the 100,000-lb./hr. boilers described in Table II represents an annual saving of £1400 in the fuel costs. The loss in output in terms of kilowatts caused by a forced stoppage of one day is valued at £1000.

As a guide to the more common causes of stoppages, Table II shows the operating results of four 600-lb./sq. in. gauge oil- and gas-fired boilers over a 12-months period. Some of the causes are recurrent and others are infrequent, but both could be reduced by special attention to design. Being gas- and oil-fired, the boilers are not troubled by heating-surface deposits, but to make the summary of recommendations more complete, descriptions of solid-fuel firing plant are included with the various design and operational requirements for continuous service.

Boiler Deposits

Under this general title are included all deposits, from combustion-chamber slag accumulations to air pre-heater and economizer alkali-bonded deposits. These two types of fouling are quite dissimilar, but the change in composition varies gradually from the combustion chamber to the preheater, according to temperature. To appreciate the problem associated with reducing these deposits, the following brief description of various firing methods includes details of the type of fouling to be expected and the remedial measures adopted in the respective operating technique.

Multiple Retort Underfeed Stoker

This is now out of favour for large central power-station boilers, owing to the severe fouling that takes place in the economizer and air preheaters, but for the efficient combustion of such a variable compound as coal it has advantages.

The severe fouling is caused by the ash being retained in the ash pit until the residual carbon is completely burnt out. At high firing rates, the ash pit approaches normal fire-bed temperature. This, coupled with the local reducing atmosphere, causes the phosphorus and boron compounds to distil, combine with the sulphur dioxide and trioxide, and sublimate in the cooler parts of the boiler heating surfaces.

The firing rate of these stokers should be such that little unburnt carbon enters the ash pit to cause these local high temperatures. In some cases of severe fouling, experimental reduction of fire-bed operating temperature, either by supplying the forced-draught fan inlet with water spray or by recirculating flue gas from the boiler chimney back to the stoker wind box, has had a beneficial effect. The use of additional pulverized-fuel firing has also assisted in some cases, the particles of grit acting as a nucleus for the formation of the deposits.

Precautionary measures in the boiler design should include the provision of several rows of widely pitched boiler tubes as a slag screen in advance of the more vulnerable superheater.

In the stoker sizes expected in industrial practice, this type of firing does not require excessive repairs and maintenance, and the stoker drive power consumption is small. The stoker is usually split up into a number of small driven units, and loss of one by breakdown does not, therefore, cause a large drop in

load. Fuels containing a high percentage of phosphorus and boron, or fuels which are weakly caking, are not recommended, and a low-fusion-point ash can cause a reduction in boiler output.

To ensure even feeding of the stoker rams, the fuel should be free-flowing, limiting the moisture content of the smaller fuel sizes to 10%. This firing method should not be used for two-shift operation, for the banking losses due to the large fire-beds become excessive.

Chain Grate Stoker

This type of firing is more likely to cause the sintered fly-ash type of deposit when the fuel used is of high swelling index, resulting in unevenness in the fire-bed with consequent high local air velocities. The entrained solids in these air streams are fused in their passage through the combustion-chamber flame and bond on the boiler or superheater tubes. Ultimately, these deposits fuse together, producing a hard dense slag. Economizer or air-heater deposits are to be expected with this type of firing only if the sulphur and phosphorus content of the fuel is high.

The stoker drive power consumption is less than for the underfeed stoker, but as the installation is subdivided into two halves a mechanical defect can cause a decrease of 50% boiler output.

Sprinkler Stoker

The sprinkler stoker in modern use consists of a forward travelling grate, to the rear of which coal is thrown. In its passage through the flame, the finer particles are burnt in suspension, the larger sizes being burnt on the grate.

A large amount of grit and fly ash is carried over into the boiler passes, settling in the grit hoppers. It is then delivered by compressed air or steam ejectors back to the fire-bed, for refining.

An oxidizing atmosphere is maintained in the ash pit, which does not give rise to the phosphate-bonded deposits of the reducing atmosphere of the underfeed stokers. This stoker is particularly successful on low-grade fuels of small size.

Pulverized Fuel Firing

The flexibility of this type of firing makes it ideal for meeting large load swings, while maintaining close regulation of fuel/air ratio. Depending on the fuel chosen, the combustion-chamber heat release is usually 18,000–22,000 B.Th.U./cu. ft./hr.

The more usual stoppages are caused either by combustion-chamber slagging or by tube failures through flame impingement by deflection on water wall tubes and slag screen tubes. The conventional soot blower is not particularly effective in removing these heavy slag accumulations. This has led to various trials using high-pressure compressed air on the intermittent puff system; the technique of water lancing for dealing with stubborn deposits is now an accepted part of operating routine.

Cyclone Firing

Partially ground coal particles are blown into a water-tube refractory-lined cyclone, which leads off the main combustion chamber. Although boilers fitted with this type of firing are claimed to be immune from slag and bonded deposits, the inherent disadvantage of having to remove the slag in the liquid state makes this type and size of boiler unsuitable for industrial purposes.

Gas and Oil Firing

To deal with the usual wide range of gas and liquid fuels in industry, the multi-port concentric type of burner is in general use. The advantages are that a combination of various fuels can be dealt with, and the burner itself takes up a comparatively small area in the combustion-chamber water wall tubes.

One of the problems of design is that of maintaining the steam temperature at the superheater outlet within narrow limits at all loads, so as to reduce the work done by attemperators, desuperheaters, by-pass dampers, and flue-gas recirculation. Variations in flame length cause differences in the ratio of heat absorbed for evaporating and superheating. Much research is being carried out in the gas-turbine industry on the problems of producing a burner to maintain constant flame length under a wide range of load. Some of the solutions already achieved could be adapted in the design of boiler gas and oil burners, with resulting economies in steam temperature-control equipment.

Choice of Firing Methods

This will depend largely upon the anticipated types and quantities of the waste fuels. Restrictions in these supplies, if protracted, will require the incorporation of alternative firing by an economical solid-fuel-firing method. Temporary reductions of short duration can be met by fuel-oil firing at a considerably lower capital cost for the plant. It needs very expert forecasting to decide which of these two alternatives is to be adopted, owing to the large changes that can occur in the surplus fuel balance of a works system. Borderline cases need additional investigation into electricity tariffs, maximum demands, liquid and solid fuel costs, gas availability, and the possibilities of fuel exchanges carried out at other parts of the plant.

The boiler plant usually has the lowest priority for blast-furnace or coke-oven gas demands, owing to the fixed requirements of departmental processes. For this reason, it is also usual to find that the boiler plant is to act in some measure as the gas pressure controller of the system. It would be quite uneconomical to install a gas holder for blast-furnace gas to act as fuel storage to meet a fluctuating demand, for the boiler sizes now becoming common in industry. The thermal equivalent of a 3,000,000-cu. ft. gas holder would be only 10 tons of coal.

BOILER WATER CHEMISTRY

The importance of feed-water chemistry, in view of the reduction in boiler water content and increase in heat-transfer rates, as exemplified in the section on boiler design, cannot be over-emphasized. There is a secondary effect that there is far less latitude for contingencies such as condenser leakages. Corrective measures in the control of boiler-water solids and the introduction of the necessary reagents require to be faster to keep the total dissolved solids in the boiler water within narrow limits.

The chemicals normally used are based on sodium and tannin phosphates, slug-dosed directly into the boiler drum, so that the chemical change to sodium orthophosphate, which is progressive as the temperature rises, should take place entirely within the boiler water. The addition of sodium sulphite and caustic soda is necessary to absorb the final traces of oxygen after de-aeration and to keep the *p*H value of the feed-water in the economizers high enough to avoid corrosion. This becomes more important in the high-duty steaming economizer and, to provide additional protection in these types without adding total dissolved solids to the boiler water, recirculation of boiler water to the economizer inlet becomes necessary.

Oxygen removal is the most important single factor in the feed-water treatment of modern high-pressure boilers. Up to 250 lb./sq. in. gauge close chemical control with high *p*H values can inhibit oxygen corrosion, but above this pressure full de-aeration is essential.

The vacuum-type de-aerator which has been popular for so many years is giving way to the pressure type, which in addition takes the place of a low-pressure feed-water heater.

As some guide to the degree of de-aeration expected, either type, for 600 lb./sq. in. gauge working pressure, should reduce the residual oxygen content to 0·01 c.c./l. At this pressure, the final traces of oxygen must be absorbed by sodium sulphite, which should be continuous at a sufficient rate to maintain an excess of 20–30 p.p.m. in the boiler water.

HIGH THERMAL EFFICIENCY

Efficiency of Combustion

The firing method adopted should aim at minimum ash-pit loss, avoidance of excessive fly-ash loss, sufficient combustion chamber volume to ensure complete combustion, and a minimum of excess air.

A knowledge of the combustion characteristics of the fuel to be used will be necessary to determine burning rates per sq. ft. of grate or per cu. ft. of combustion chamber. Unusual properties such as abnormal flame length require combustion-chamber sizes that will permit complete combustion. Fly-ash loss from pulverized-fuel firing tends to increase rapidly with grinding fineness of less than 85% through 200 I.M.M. mesh, particularly with coals yielding hard coke.

The excess air requirements for complete combustion should be at a minimum, at the same time avoiding the formation of carbon monoxide. With single fuels this is best checked by a direct gas analysis from a knowledge of the carbon/hydrogen ratio.

For mixed-fuel firing, the air required by each fuel should be controlled by the fuel flows, according to a pre-set ratio, the final check being the surplus oxygen in the flue gas. Oxygen meters are being installed for this purpose, but their reliability is not yet high enough to operate a completely automatic boiler-control system from them.

Air infiltration is no longer a problem with modern steel-cased boilers, and the loss in CO_2 by air leakages from the boiler exit to the air-preheater exit should not exceed $1\frac{1}{2}$%.

Ratio of Heat Transferred to the Steam

The amount of heat transferred from the combustion process to the steam, water, and air will be largely dependent upon the heat losses by radiation, and the final temperature at which the flue gas is to be rejected to waste.

The use of furnace refractory always contributes to a high proportion of radiation loss, as it is a matter of close design how much insulating material can be used outside the refractory. If an excessive amount of insulating material is applied, the refractory attains combustion-chamber temperature, with a considerably shortened life. In such cases, where for flame stability it is necessary to use refractory, some boiler layouts circulate preheated air for combustion outside the refractory, which then imposes no limitations on the amount of insulating material to be applied inside the boiler casing. Alternatively, plastic refractory applied to studded combustion-chamber tubes may be used. This is probably the best method, for the refractory area can be varied to suit changes in fuel quality.

The final temperature at which the flue gases are to be rejected to waste should be decided from the knowledge of the sulphur content of the available fuels. A safety margin of 40° F. over the dew point, elevated by the sulphur trioxide present, should be sufficient. Any increase of overall efficiency by depressing this final gas temperature still further must also be accompanied by the use of special materials in the final air preheater to withstand sulphur corrosion. In many cases the use of vitreous-enamelled mild-steel tubes is proving satisfactory, and in the case of rotary air preheaters the use of easily replaced aluminium sections is becoming common.

As further aids to heat recovery, continuous blow-down systems coupled with flash-steam recovery are widely adopted in industrial boiler plant. The use of flash steam should be confined to feed heating and other similar purposes, but it should not be used where the high proportions of entrained boiler-water solids would be a disadvantage.

The limitations of the Rankine steam cycle are already well known, and consideration must be given in future industrial boiler installations to the possibility of using part of the boiler for reheating. Although this system has not been widely adopted, there is no doubt that for some purposes, such as mixed-pressure turbine operation, it offers increased economy without undue plant complications.

It presents the boiler designer with some critical problems on gas and steam temperature control, but experience in the behaviour of superheater materials at elevated temperatures is accumulating rapidly.

CONCLUSION

The paper has broadly outlined some of the present stages of development in the water-tube boiler industry. It is logical to expect that future designs will achieve present-day outputs with considerable economies in material and space requirements. Designs which are today regarded as experimental will become standard practice in the future.

The accumulated experience derived from a study

of these problems and the solutions already achieved, mentioned in this brief review, have equipped the British water-tube boiler industry with the means of making valuable contributions to future developments.

Acknowledgments

The author wishes to express his gratitude to the Steel Company of Wales Ltd. for permission to present the paper. He also wishes to acknowledge the help given by various colleagues in the preparation of the statistics and diagrams.

Thanks are also due to the following, for their advice and assistance: British Electrical Authority; Ministry of Fuel and Power; John Thompson Water Tube Boilers Ltd.; Babcock and Wilcox Ltd.; Simon Carves Ltd.; Richardson Westgarth (Hartlepool) Ltd.; and the General Electric Co., Ltd. (Messrs. Fraser and Chalmers).

Treatment of Water for the Iron and Steel Industry

By A. J. Lamb and A. H. Waddington, B.Sc., A.R.I.C.

SYNOPSIS

Large quantities of water have been used in industry for many years, but the question of quality has only recently been given serious consideration. Characteristics of water derived from a similar source vary greatly, but the authors have endeavoured to give a general description of the types usually available, the treatment necessary to make them suitable for particular purposes, the design of plant that can be used to effect the treatment, the chemical reagents more commonly used, and plant control. 892

WATER is very important in modern industry, and those responsible for siting new or extending existing works must ensure that adequate supplies are available. In view of the large quantities of water often required it would not be a practical proposition to transport it like other raw materials. However, the presence of large quantities of water is not alone sufficient; its quality must be considered and tests made to ascertain whether it is suitable for the purpose required. If it is not suitable in its natural state, means of making it so economically, from the point of view of both capital cost of plant required and cost of treatment, must be sought. The question of quality has only recently been considered seriously and placed on the same level as the quality of other raw materials used in manufacture, which are subject to regular and careful examination. Nevertheless, it is still possible to find many works where the quality of water has not received any consideration or where an obsolescent water-treatment plant is expected to deal with a larger quantity of raw water of inferior quality to that for which it was designed. It is unusual to find a supply of water which is suitable in all respects and does not require some form of treatment.

In the preparation of schemes of water treatment, there must be the closest co-operation between the engineer and the chemist in all stages, even from the first discussions and possibly even, in the case of a new plant, before the choice of site and water supply. For many years water treatment was regarded as an art and, despite the many recent scientific advances in water purification, it remains to a large extent an art rather than a science.

SOURCES OF WATER

In all factories where large quantities of water are used per ton of product it is neither feasible nor economical to use the municipal supply, so that resort has to be made to lakes, ponds, rivers, and streams. Very occasionally a factory is sited at a point where deep-well or bore-hole water may be used, but such cases are exceptional. In these days of commercial development, especially in highly industrialized areas, rivers and streams, as well as receiving sewage, also receive large volumes of industrial effluents and in general the character of the water to be purified is that of a very highly polluted source. Generally speaking, waters such as the Mersey and the Calder are highly mineralized, contain large concentrations of suspended solids, much of which is colloidal in character, and often contain a large concentration of oxidizable organic matter. If stored for any length of time before use they are likely to turn septic and produce the various products of decomposed organic matter. The hardness of such waters varies between very wide limits, and often the proportion of permanent (non-carbonate) as distinct from temporary (carbonate) hardness will vary even if the total hardness does not. Mills may be sited on tributaries of rivers which during the summer season receive very little water, and consequently the volume available is distinctly limited. When this is the case, treatment is made much more difficult, since the composition will vary not only daily but often hourly. Water supplies derived from lakes are to a certain extent averaged out but, depending upon the configuration of the lake or pond, such supplies are subject to additional change in the seasonal growths of algæ and other micro-organisms, which can often cause serious difficulties in the purification plant.

Obviously, deep-well or bore-hole water, which is often harder than supplies derived from lakes or

Manuscript received 4th January, 1954.
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Fig. 1—Dry chemical feeder

rivers, is much more constant in composition; in general the treatment of such a supply is much easier than is the case with the other sources of supply mentioned. These waters may on occasion, however, contain iron and manganese in relatively large amounts which, if not removed, will cause difficulty in the distribution system.

Whenever possible, adequate raw-water storage and settlement should be provided, because such storage will often enable a spate or flood in the river or stream to be by-passed and so keep a more average water supply available. The retention time in such a raw-water storage reservoir will allow almost all the coarser suspended matter and often a small proportion of the finer material to settle. This reduction in the suspended solids will lead to economy in the expensive coagulating chemicals required later. Most river and stream waters have very high chlorine-absorption values, and it may be found desirable to prechlorinate the water entering any raw-water storage reservoir, because such chlorination, although it is not sufficient to satisfy the whole of the chlorine demand, will reduce the onset of any plankton growths or decomposition of organic matter. All river-derived supplies require clarification and settlement before filtration.

USAGES OF WATER

One of the first steps is to decide the quantity of water required for the various purposes. For industrial use the purpose for which water is required generally falls into one or more of the following main groups:

(i) Boiler feed or steam raising
(ii) General process work, such as cooling
(iii) Manufacturing.

For the iron and steel industry (iii) has no relevance.

The treatment of water for steam raising has, in view of the increase in boiler working pressures and the more general use of water-tube boilers, received a great deal of attention in the last few years. Whereas at one time the installation of a lime-soda or base-exchange plant, which might not receive attention, was thought to be adequate, the question receives much more thought nowadays. As, however, treatment for boiler-feed purposes is often additional to or in conjunction with treatment for process purposes, it is desirable to deal with the latter first.

Among the process purposes for which water is used in the iron and steel industry are:

(i) *Hot-Rolling Billet or Slab Reheating Furnaces*—Cooling discharge door and nose arch lintels, skids, bearings on hot-air fans of recuperators, rotating agitator arms on producer-gas fired furnaces, and oil-burner cooling jackets on oil-burning furnaces

(ii) *Hot-Rolling Mills*—Slab or billet descaling through jets, roll cooling by direct application, bearing cooling by direct access or occasionally through coils, strip cooling before coiling, and operating manipulative gear (oil is often used nowadays)

(iii) *Cold-Rolling*—Direct water-cooling to rolls and open-type brass, phosphor-bronze, or white-metal bearings where wet rolling is carried out and suitable oils are used to protect the strip, cooling rolls by circulation through a hollow bore (modern mills use soluble oils and water, except the Zendzimer, which uses mineral oil for bearing lubrication and strip cooling), cooling oil used for bearing lubrication, and strip cooling; also spray washing for the acid portion of the pickle tank on continuous pickling plants

(iv) *Annealing*—Cooling oil used for sealing bases of top-hat-type bright-annealing furnaces, sections of bright-annealing gas-atmosphere plants and the gas itself, and bearing housings and cooling chambers on roller-hearth annealing furnaces.

Similar applications are found on rod-rolling mills and wire-drawing plant. Water is also required for cooling gas-port noses, charging-door frames, air and gas reversing dampers, gas reversing valve seal pans, etc., on open-hearth furnaces.

QUALITY OF TREATED WATER

So far as the quality of the water is concerned, the main considerations are that it should not contain suspended matter, which would deposit in pipe-lines and tanks and mark steel sheets in rolling mills, algæ, which form a slimy deposit on surfaces when the temperature of the water is raised, or excessive temporary hardness, which might be precipitated in some parts of the circuit where higher water temperatures are reached and might be non-corrosive. Filtration as a means of obtaining clear water is only satisfactory if the only impurity to be removed is a small amount of mineral suspended matter. Generally, additional treatment is required, particularly when dealing with a surface supply, and this adjunct to the proper utilization of rapid gravity or pressure filters as compared with the older slow sand filters is coagulation and settlement. Suspended matter in water usually includes some finely divided or colloidal impurities which would not be removed by filtration alone, and the object of coagulation is to convert the latter into aggregates which quickly settle out or are easily removed by filtration. Therefore, to obtain and maintain water as indicated from a surface supply, the method of purification would comprise chemical treatment, including the addition of softening reagents for a water of high hardness, flocculation, sedimentation, filtration, and chlorination, to prevent algoid growths. Such treatment might be considered too elaborate or indeed unnecessary, and the capital outlay too great, and it might be thought that pressure filters inserted in a pumping main would be satisfactory. Pressure filters have a very important

place in the purification of water, but they are not to be recommended for use alone to treat a turbid variable surface supply. There have been many cases where during periods of high turbidity the filter runs have been reduced to 1–2 hr. and difficulty has been experienced in maintaining a sufficient output of filtered water for process use, owing to reduction in filtering capacity due to one or more of a battery of filters being out of operation for cleaning, and thereby increasing the demand on the output of the remainder for wash-water. The bigger capital outlay for plant for the more complete treatment is invariably justified and is, in fact, recouped in the long run.

Another point which should receive consideration is the provision of ample storage for treated water to act as a balance tank between the treatment plant and the works, where the demand for treated water is usually variable, sometimes between wide limits, and also for the supply of wash-water for the filters. Ample treated-water storage also enables the plant to be operated at a more or less constant rate, thus allowing a less elaborate type of chemical apparatus to be used and simplifying control.

For the treatment outlined a gravity plant is preferable; when dealing with flows above about 15,000 gal./hr. the design lends itself to reinforced-concrete construction for the tanks, which involves almost no maintenance costs compared with steel.

Chemical Treatment

The first step in the treatment process is the preparation and addition of chemicals. The type of equipment used depends on site and operating conditions, but the main considerations are that it should be robust in construction and simple in operation. If the chemical to be added can be obtained in a dry powder form, a dry-feed equipment offers many advantages, as it eliminates labour costs for preparing a chemical solution or suspension. One type of dry feeder is shown in Fig. 1. This equipment measures the powder by volume and is provided with a revolving table carrying the powder, which is discharged through an opening that is adjustable while the machine is in operation by means of an external handwheel. The measured powder can be discharged in a dry form to the point of application through a chute or it may

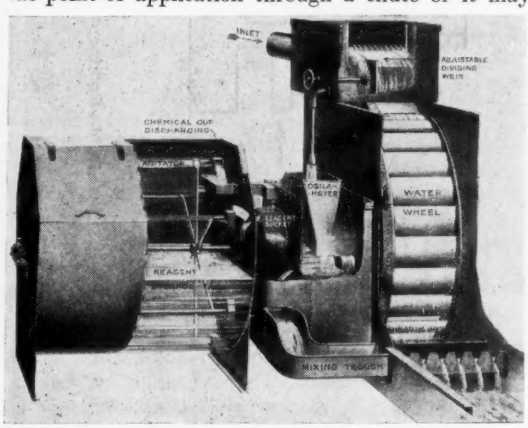


Fig. 2—Proportioning equipment for chemical solution or suspension

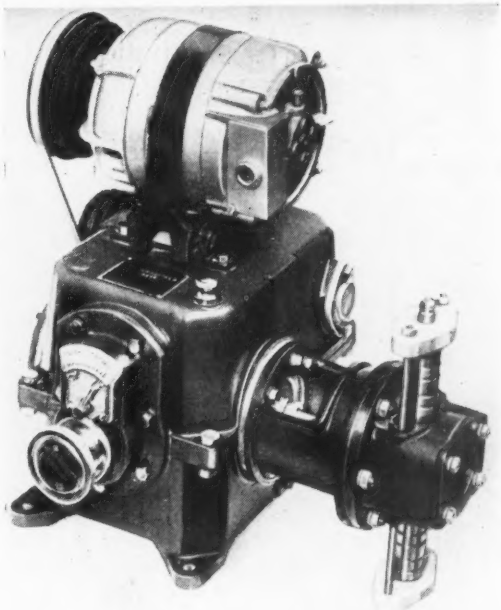


Fig. 3—Motor-driven chemical injection pump

be first mixed with water in a vortex mixer. The machine is fitted with a small storage hopper, but if this is not of sufficient capacity an extension hopper can be connected to it through a flexible coupling and shear gate.

The general practice is for the dry feeder to operate at a constant rate of discharge, which can be set by hand at any rate up to the maximum output of the feeder. If, however, the quantity of water being treated is variable, the feeder can be arranged to give a proportional feed of chemical by the provision of a variable-speed motor and control gear actuated from the level of water passing over a weir or by the flow through a Venturi tube or orifice fitted in a pipe main.

If a liquid feed is used, a primary requirement is that the preparing and storage tanks, particularly for insoluble reagents such as lime, chalk, etc., should be fitted with adequate mixing devices, to ensure the preparation and maintenance of a solution or suspension of consistent strength, and facilities for cleaning. For reagents such as hydrated lime the tank should be covered to minimize egress of dust which will ultimately settle on other machinery in the building, as well as being objectionable to the attendant preparing the chemicals. The measuring equipment should be easily adjustable and designed if possible to deal with any type of liquid, *i.e.*, with a chemical in solution or suspension. An equipment to deal with the latter can generally be used for the former, but the reverse does not apply. The modern tendency is for the equipment to be fitted at ground level; when dealing with up to about 20,000 gal./hr. this often involves, particularly when the water flow is variable, the use of an equipment that is more elaborate and costly than some of the older types of apparatus. The older equipments have proved very satisfactory and are capable of giving long service

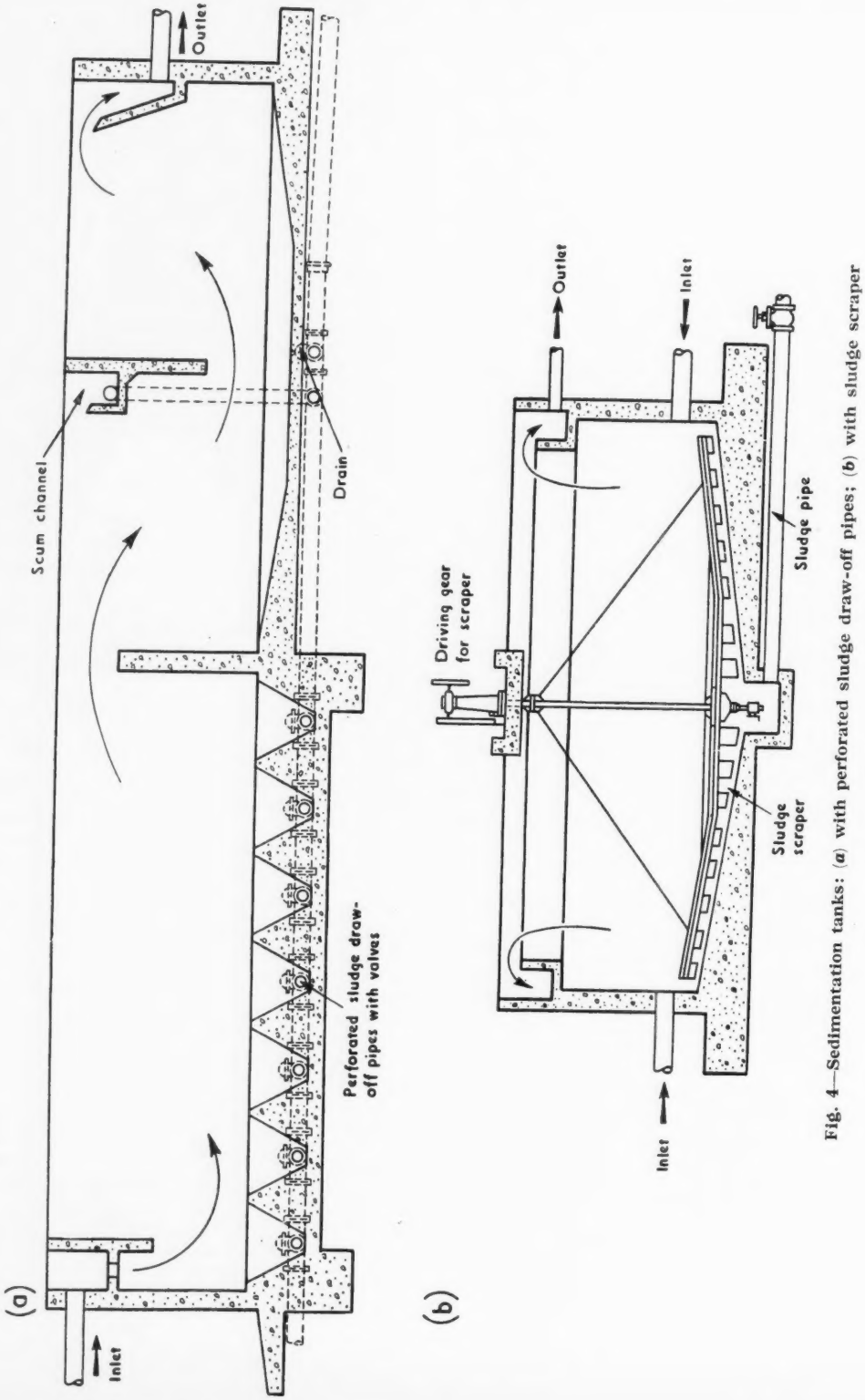


Fig. 4—Sedimentation tanks: (*a*) with perforated sludge draw-off pipes; (*b*) with sludge scraper

with the minimum of attention and maintenance; their only drawback is that they have to be elevated, usually on top of the reaction or settlement tank, and are frequently open to the elements. A chemical apparatus of the latter type is shown in Fig. 2.

This type is suitable for treating a variable flow of water and for use with a liquid with the chemicals either in solution or suspension. A modified apparatus can be fitted at ground level, using a proportion of raw water by-passed from the main flow and a pump to elevate the by-passed water and measured chemical to the sedimentation tank. Other types of apparatus include a water meter with electrical contacts fitted in the raw or treated water main, which controls a motor-operated chemical valve and/or pump at intervals after predetermined quantities of water have passed through the meter, and chemical measuring pumps operated hydraulically through a pilot valve from a meter fitted in the raw or treated water main. If the quantity of water being treated is reasonably constant, a motor-driven chemical measuring and injection pump (Fig. 3) will prove very satisfactory.

For larger flows of water, the question of the type of chemical apparatus is simplified in view of the greater quantity of chemical to be measured. The plant usually includes a building to accommodate pumps and chemical preparing equipment and to cover filter fronts, etc., when the provision of an elevated platform or floor to carry the chemical measuring apparatus does not unduly add to the capital outlay. For this type of plant a very satisfactory arrangement is to pass the incoming raw water over a weir and use a float riding on the water level to operate chemical measuring apparatus, *e.g.*, a taper valve or adjustable weir for solutions and a dividing weir for suspensions; dry chemical feeders for constant or variable flow may also be used.

After the measured chemicals have been added to the water the two have to be intimately mixed for sufficient time, in some cases up to 30 min., to enable the fine or colloidal impurities to be coagulated, thus assisting precipitation. The mixing and flocculating tanks can be of vertical or horizontal construction and may include slowly rotating paddles driven by an electric motor or a water wheel operated by the incoming water.

SEDIMENTATION

The flocculated water now requires sedimentation to enable the bulk of the suspended impurities to be precipitated before filtration. For many years the question of design of sedimentation tanks has received considerable attention, and numerous types have been designed and in many cases tried out either experimentally or under practical conditions. Some features are more or less common to all types, and the basic points of design for a satisfactory tank are equal distribution of unsettled and withdrawal of settled water, low velocity through the tank, and efficient sludge collection and removal systems.

The rectangular sedimentation tank with perforated sludge draw-off pipes on the bottom shown in Fig. 4*a* is used very frequently with satisfactory results. However, if the raw water contains a large amount of suspended matter and high doses of coagulants are used, a voluminous precipitate will be formed, possibly of a gelatinous nature, necessitating frequent sludging to prevent excessive build-up and reduction in sedimentation capacity. If this does occur, the tank has to be drained and the sludge hosed out, and so the tank should be designed with a central longitudinal dividing wall, thus enabling one half to be cleaned at a time and not stopping the output entirely. Another type of tank (the sludge scraper tank) is provided with sludge extraction mechanism as shown in Fig. 4*b*; such a tank is to be preferred for waters containing large amounts of suspended solids. The sludge extraction mechanism is power-driven by motor or water wheel, and can be operated continuously or intermittently as desired; it is usual to provide a handwheel for manual operation when necessary. With heavily polluted waters it has at times been found desirable to use both tanks in series, using the sludge scraper tank for preliminary and the type in Fig. 4*a* for final sedimentation. Opinion is divided as to whether sedimentation tanks should be square, round, or rectangular; possibly the ideal tank has yet to be designed.

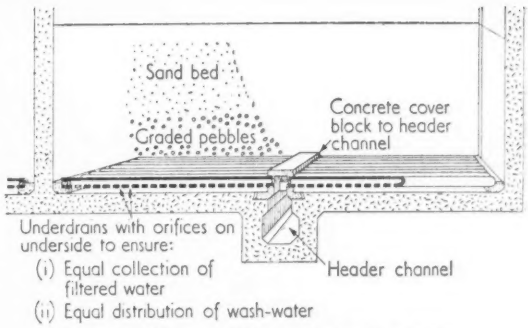

Sand bed
Graded pebbles
Concrete cover block to header channel
Underdrains with orifices on underside to ensure:
(i) Equal collection of filtered water
(ii) Equal distribution of wash-water
Header channel

Fig. 5—Non-metallic underdrain system

FILTRATION

Coagulation and sedimentation should produce water having a turbidity of not more than 20 parts per million, and such water is suitable for filtration. Filters can be of the gravity or pressure types, but when dealing with a coagulated and settled water which eventually has to be delivered to an elevated storage tank or into a pressure main it is not good practice to pump the settled water through pressure filters, as this would tend to break any fine floc formed in the sedimentation tank, thereby reducing the efficiency of the filters. A much more satisfactory method is to allow the water to gravitate through filters to a sump and then pump it out. It is often erroneously stated that water is forced through a pressure filter, implying that as the flow decreases owing to dirty media the application of higher pressure would increase the output. This would tend to force suspended matter into the filter bed, making cleaning *in situ* more difficult or impossible if carried on for too long. The media in a pressure filter should be cleaned when the pressure drop between the inlet and outlet is of the order of 10 ft., which is little more than the loss in head through the media in a

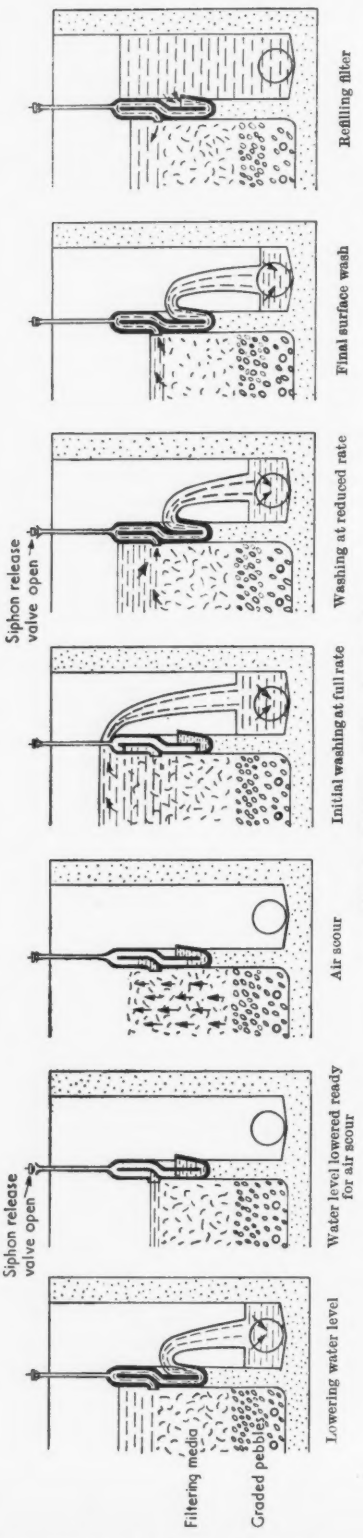


Fig. 6—Siphon waste draw-offs

gravity filter before cleaning. The main advantage of a pressure filter is that it can be inserted into a pumping main without losing all the pressure; its disadvantages are that the surface is not open to inspection and observation of cleaning efficiency is difficult. Pressure filters can be of vertical or horizontal steel construction, the maximum size of the former usually being 8 ft. dia. × 4–5 ft. high and of the latter 8 ft. dia. × about 24 ft. long. Gravity filters can be of circular or rectangular steel or concrete construction and of any size.

For satisfactory operation, a filter must be provided with efficient distributing and collecting systems to ensure that the whole area is used and short-circuiting does not occur. Distribution of unfiltered water and collection of waste water from the washing process is usually effected by a bell mouth in the centre in the case of vertical pressure filters and a trough or troughs for horizontal pressure and gravity filters; the lip of the bell mouth or trough is usually about 1 ft. above the top of the filtering media. Collection of filtered water and the distribution of wash-water in both pressure and gravity filters are usually effected through orifices placed a few inches apart in lateral tubes connected into a central header on the floor of the filter; the header may be a steel or cast-iron pipe and the lateral tubes copper. Alternatively, a non-metallic system consisting of a concrete header and asbestos-cement lateral tubes can be used; this is more usual with concrete gravity filters and the larger pressure filters. A typical system is shown in Fig. 5. The filtering bed consists of about 17 in. of graded pebbles varying in size from 1½ to ⅛ in., on which is supported a bed of washed and graded sand or anthracite about 2 ft. deep.

A very important aspect of satisfactory filter operation is efficient cleaning of the media at intervals depending upon the amount of suspended solids to be removed and the speed of filtration. The method most frequently used is agitation with air to loosen the impurities adhering to the media, which are then washed away by an upward flow of clean water; this is continued until the waste water runs clear, as seen in a sight glass or open sump.

The use of power-driven mechanical rakes for agitating the bed in vertical circular filters appears to be falling into disuse, probably owing to the high running and maintenance costs; the use of rakes is nowadays generally confined to vertical-pressure filters up to about 5 ft. dia. when they can be manually operated. A comparatively recent improvement, particularly for larger gravity filters, is the use of controllable siphons for withdrawing the dirty surface water left above the bed after normal washing by a rapid flush instead of continued dilution. When the wash-water applied at the normal rate begins to spill over the waste-collecting channel, the rate of flow is reduced by 50–75% and the level is lowered by discharging through syphons fitted in the waste-channel wall and controlled by manually operated valves. By using the siphon waste discharge, economy in wash-water and increased efficiency of the washing process are obtained by giving a horizontal surface wash across the filter bed. Siphon waste draw-offs are shown in Fig. 6.

CONTROLS

Various controls and equipment are available to assist the attendant in the efficient operation of rapid gravity-filtration plant and the maintenance of complete records; although they might be unnecessary refinements in industrial water-treatment plant, the additional capital outlay involved is more than justified. The following may be used:

(i) Rate controllers for maintaining a constant output from each unit and preventing a flow in excess of any pre-set rate

(ii) Slow-start apparatus for bringing a filter gradually into operation after washing

(iii) Indicators and recorders for rate of flow and loss of head from each filter or the whole battery of filters; those for loss of head enable the washing process to be performed at the correct time, thus giving maximum efficiency and minimum wash-water

(iv) Rate controllers and recorders for wash-water to ensure application at the optimum rate, thus combining efficiency of cleansing with economy of water

(v) Control tables for centralizing the operation of filter valves, etc., thus hydraulically eliminating the manual effort

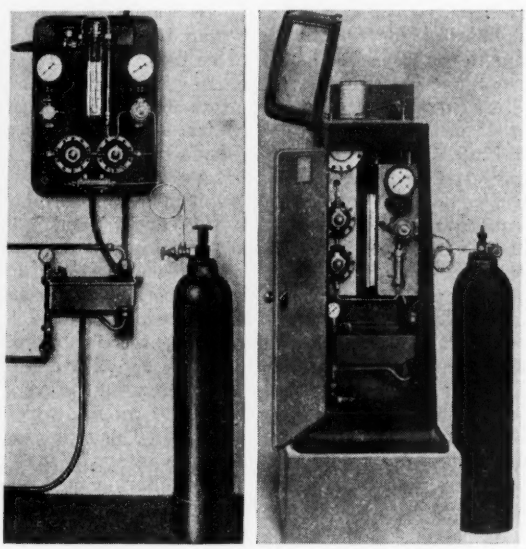
(vi) Sampling tables providing centralized points where samples of raw and filtered water can be taken at any time

(vii) Master controls for uniformly closing down or altering the rate of flow through each of a battery of filters.

CHLORINATION

The filtrate will be a clear, practically colourless supply which now requires the addition of a small dose of chlorine, particularly if the temperature is to be raised, *e.g.*, in a cooling circuit, to prevent the formation of algoid growths, which would reduce efficiency and ultimately the flow through the circuit. Either chlorine gas or sodium hypochlorite can be used, but as the running costs with the latter are much higher than when gas is used its use is generally confined to comparatively small water flows or to sites where gas is difficult to obtain. Chlorine in a liquid form is obtained in cylinders containing about 70 lb. or drums containing about 15 cwt. Gas is drawn off at the outlet owing to expansion; this gas is measured in a special panel comprising the necessary pressure-reducing and regulating valves and measuring meter, with a scale reading in lb./hr. or the equivalent. The measured gas is formed into a solution by admixture with a minor supply of water, and this chlorinated water is added to the water to be treated. For the formation of the solution an absorption tower or injector can be used, depending on the point of application, *i.e.*, in an open sump or pressure main. Apart from the treatment of filtered water, chlorine has proved to be very effective in the prevention of algoid and other growths when river or similar water is used for condenser cooling purposes; in these cases either the continuous or the intermittent system of dosing can be used. A typical chlorine control panel is shown in Fig. 7*a*. If desired, a recorder can be fitted to the chlorine measuring equipment to give a chart record of the times at which chlorine is applied and the amount passing; alternatively, the measuring equipment and recorder can be accommodated in a pedestal case, as shown in Fig. 7*b*. Apparatus can also be obtained to give a chart record of the amount of residual chlorine in water. The water being tested is connected to the apparatus and samples are continuously measured and treated with the required dose of testing solution; the resultant colour is measured by a photo-electric cell and the equivalent residual chlorine is marked on the chart.

Sodium hypochlorite is obtained in carboys and after dilution can be added by gravity-feed equipment or a motor or meter operated pump; apparatus is available for producing sodium hypochlorite electrolytically from salt.



(a) (b)

Fig. 7—Chlorine measuring apparatus: (*a*) Chloronome; (*b*) Chlorograph

SOFTENING

If a water contains any calcium and/or magnesium salts as bicarbonates or sulphates in any appreciable quantity it is said to be hard and the question of whether it requires softening has to be considered. The answer depends on the purpose for which the water is required. In most industries steam-raising plant is used, and invariably the water used as make-up has to be softened and/or conditioned. The extent of the treatment is governed by boiler pressure, percentage make-up, etc. For general works purposes in the iron and steel industry soft water is not essential, but if the raw water has a high hardness and is used for cooling purposes, removal or reduction of the temporary hardness in particular is very desirable to prevent deposition when the temperature of the water is raised. To remove the temporary hardness lime is used, and a softening dose could be added to the water in the clarification plant already described; in this case the temporary hardness will be removed from all the water, which may be considered unnecessary if only a small proportion is used for purposes which may cause precipitation of the temporary hardness, *e.g.*, in a cooling circuit. The alternatives are to clarify and soften the water used for these purposes in a separate precipitation-type of plant or

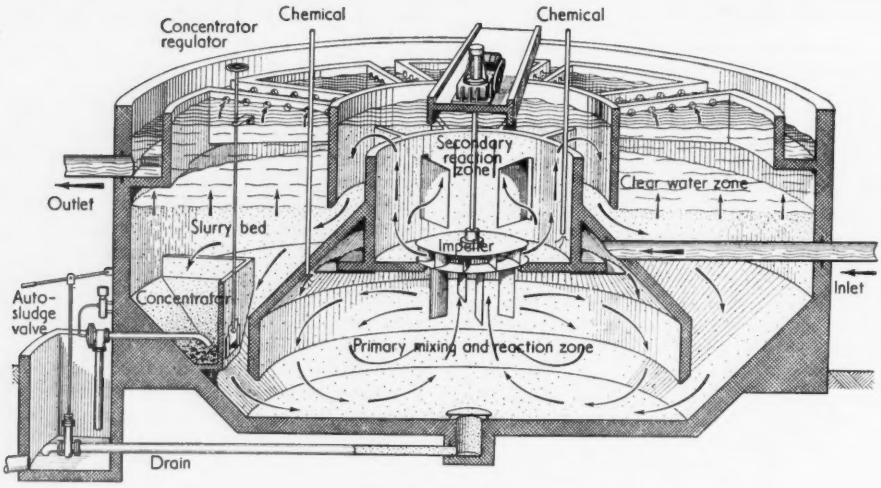


Fig. 8—Accelator

to take a proportion of the clarified water and remove all the hardness in a zeolite softener. Clarification and softening all the water in one plant might, however, be more economical and practicable, from the point of view of both capital and running costs.

The treatment of water for steam-raising plant should be such as to prevent steam contamination, corrosion and deposits in feed mains and tanks, return condensate pipes, feed heaters, economizers, etc., and scale, sludge, and corrosion in the boiler itself, the elimination of gases, *e.g.*, oxygen and carbon dioxide, and the risk of caustic embrittlement. In addition, means should be available to control the concentration in the water in the boiler to prevent carry-over.

For some time the tendency has been to increase the working pressure of boilers, and nowadays it is not uncommon for boilers to operate at pressures of 1000 lb./sq. in. For the purposes of water treatment, up to 250 lb./sq. in. is low pressure, 250–500 lb./sq. in. is medium pressure, and 500–1000 lb./sq. in. is high pressure. The quality of the feed water for the higher pressures is much more critical than for the lower pressures, because with the high ratings used the formation of even a small amount of hard scale is liable to cause tube failure. Up to 250 lb./sq. in. water with a hardness of not more than 30 p.p.m. and a *p*H of not less than 8·5 could be used, preferably with the addition of a conditioning reagent into the feed line or boiler. For the higher pressures the aim should be a water of zero hardness, low oxygen content, involving both mechanical and chemical deaeration, and a low soluble solid content, with the addition of phosphate direct into the boilers to precipitate as a soft sludge any hardness due to inadequate control of the softening plant or condensate contamination by cooling water.

Processes

For softening water the types of plant available may be broadly divided into two groups:

(i) Precipitation
(ii) Exchange processes.

and either or a combination of the two can be used. With the former, the reagents used are lime, lime–soda-ash, caustic soda, or caustic-soda–soda-ash plus a coagulant. After the reagents are added the treated water is delivered into a reaction and precipitation tank; this will be of 1–6-hr. capacity, depending on the quality of the water and whether hot or cold softening is being used, or of about 1-hr. capacity with the accelerated reaction system in which the raw water and chemicals are mixed with sludge formed from previous reactions. Since its advent some years ago, the latter system has proved its efficiency and advantages, *e.g.*, lower turbidity, more stable water, smaller size, etc., in many instances, and it may ultimately supersede the older type of plant. One type of accelerated reaction tank is shown in Fig. 8. The treated water leaving the reaction tank should have a turbidity of not more than 15 p.p.m., but as it is desirable to use a water free from turbidity the usual practice is to pass it through gravity or pressure filters containing sand or anthracite; anthracite is used particularly with hot water to prevent silica pick-up. When a lime or lime-soda softened water is passed through sand or anthracite the calcium carbonate tends to grow on the grains instead of forming a precipitate (a form of catalytic reaction) and it is practically impossible to remove it all in the washing process. The grains therefore increase in size, thus increasing the depth of bed, and periodically some has to be removed; ultimately the complete bed is replaced. This growth could be prevented by stabilizing the water with phosphate or CO_2 before it enters the filter, but this on the other hand would prevent reduction of the hardness by 10–20 p.p.m., which occurs if unstabilized water is filtered. This reduction in hardness is considered to be an advantage by many engineers, and replacement of the filtering media is looked upon as a necessary running cost.

With the ion exchange process the raw water is passed through a bed of material which has the property of changing hardness and other salts in the water to less objectionable salts so far as boiler feed

water is concerned; these materials are generally, though loosely, termed zeolites. The earlier types were siliceous compounds used to exchange calcium and magnesium in the water for sodium and were regenerated with sodium chloride. Recently many new materials have been produced, which have the same properties as the older types when regenerated with brine; if regenerated with acid instead of brine, however, they have the property of exchanging hydrogen ions for sodium, calcium, or magnesium ions; *i.e.*, the salts are converted to the corresponding acids. By the use of cation and anion zeolites in the proper combination and sequence of regeneration with acid and alkali it is possible to obtain a water equivalent to distilled water, but the cost (capital and running) is considerably in excess of that for removing hardness only. With the development of highly basic anion exchange materials it is also possible to remove the weak acids such as CO_2 and silica, but gaseous CO_2 is normally liberated by aeration. Zeolites or base-exchange materials may generally be summarized into the following types:

(i) Siliceous (natural and synthetic)
(ii) Carbonaceous (sulphonated coal products)
(iii) Resins (condensation product of reaction between phenols and formaldehyde, and the more recent group produced by polymerization processes).

The exchange value varies from 5000 grains of $CaCO_3$ per cu. ft. for the natural material to 20,000 grains/cu. ft. for the modern resins with a salt consumption of 0·25–0·5 lb. per 1000 grains removed. Another method of softening the water is by a combination of the precipitation and zeolite types, which would probably reduce the cost of softening and eliminates the disadvantages of straight zeolite softening on the sodium exchange from the point of view of quality of the treated water. With the combined process the temporary hardness is removed by lime in the precipitation softener, and the settled water is filtered, treated with acid to reduce the *p*H, and then reduced to zero hardness in the zeolite unit; the quantity of acid added can, if desired, be automatically controlled by means of a *p*H recorder and controller.

The type of treatment to be used is dependent upon boiler pressure, quantity of make-up, etc., and a careful investigation of the quality of raw waters available should be made before reaching a final decision. Generally, the water used as boiler feed is a mixture of condensate and treated water and the proportions can vary considerably; for example, at electricity generating stations there may be 90% or more condensate, whereas when steam is used for both power and process the condensate is considerably less, and in some cases is nil. The boiler feed would therefore be treated water only.

OIL REMOVAL

Condensate from steam turbines or evaporators can generally be returned for boiler-feed purposes without any treatment other than conditioning after mixing with the softened make-up. On the other hand, the condensate may be contaminated owing to condenser leakage, which can be rectified by chemical treatment; this should only be considered a temporary measure and the first opportunity should be taken to repair the cause of the leakage. Condensate from reciprocating engines and process plant may contain oil, and it is essential that this should be removed before the condensate is returned to the boiler feed circuit. If the percentage of condensate is small, the oil can be removed by mixing the condensate with the raw make-up and treating the mixture in a precipitation-type softening plant. If this is impracticable or the percentage of condensate is high, the oil can be easily removed in a separate plant; the condensate is treated with aluminium sulphate and soda which flocculates the oil, thus enabling the bulk of it to be precipitated and the last trace to be removed by filtration through anthracite. Many plants of this type are in use. In recent years, promising results have been obtained in removing oil from condensate by passing it through a pressure filter of the element type, using kieselguhr as a filtering medium; this type of filter, shown in Fig. 9, is known as the Stellar filter. It can be used for filtering any liquid, *e.g.*, oil, wine, gelatine, spirits, etc., and it is being used in a large number of industries. A number are installed on a rolling mill at a steelworks for filtering oil used for rolling, bearings, etc. When dealing with water, the degree of filtration is higher than that obtained from sand filters, and such filters should be considered when it is desired to obtain high-purity water for special purposes.

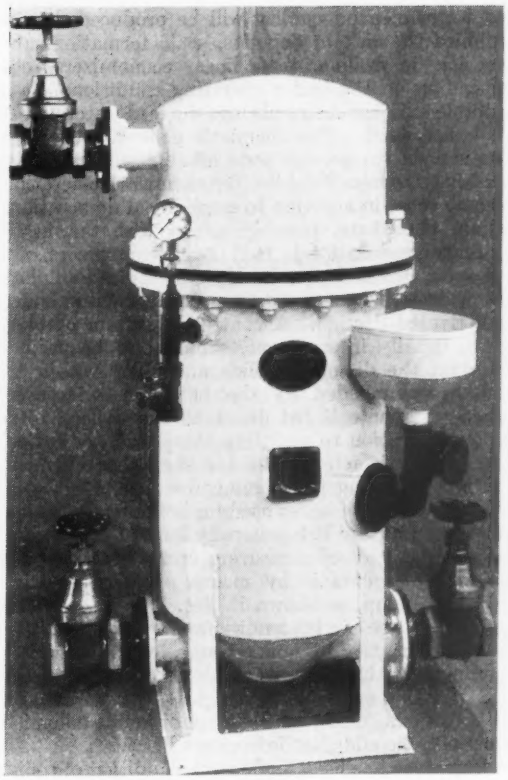


Fig. 9—Stellar filter

FEED-WATER CONDITIONING

With one or more of the treatments described, boiler

feed water of good quality will be produced, but to minimize the risk of deposits, scale formation, and corrosion in boilers, feed lines, economizers, etc. (depending on the boiler operating conditions), it is desirable to inject chemicals into the feed water and/or the boiler itself. The chemicals generally used are caustic soda (to provide soda alkalinity to minimize corrosion), sodium sulphite (for chemical de-aeration, in some cases in addition to mechanical de-aeration), sodium phosphate, possibly mixed with tannin (to minimize incrustation in feed lines, economizers, etc., and scale in the boiler itself), and sodium sulphate (for protection against caustic embrittlement in boilers with riveted drums). A controlled system of blow-down, usually intermittent, should also be used to maintain the dissolved solids and silica within the limits recommended by the boiler manufacturers. When phosphate is fed direct to the boilers, intermittent injection to maintain the phosphate ratio is generally satisfactory, but for the other chemicals continuous dosing is recommended.

The quantity of water used for boiler feed is reasonably constant and it is generally found that the most satisfactory way of measuring and adding the conditioning reagents is by means of a motor-driven injection pump, as shown in Fig. 3. In some cases the feed water can be conditioned by recirculation of a small quantity of boiler water, which reduces to a minimum the amount of blowdown and thereby the quantity of make-up and loss of heat and conditioning chemicals, so that conditioning chemicals need only be added at infrequent intervals.

Reference has been made to the addition of sodium sulphite for chemical de-aeration; this does not, however, supersede treatment in one of the standard types of mechanical de-aerators. Experience shows that for boiler pressures up to 250 lb./sq. in. a mechanical de-aerator is not essential, as there is usually sufficient alkalinity in the boiler water to resist corrosion; at pressures between 250 and 500 lb./sq. in. a dissolved oxygen content of not more than 0·02 ml./l. should be the aim, although it is often as much as 0·5 ml./l.; and above 500 lb./sq. in. complete removal of dissolved oxygen is desirable. To obtain this, mechanical de-aeration is augmented by chemical de-aeration.

COAGULANTS AND COAGULANT AIDS

Aluminium Salts

The group of chemical reagents used before settlement and filtration are known as coagulants, and the most common example is aluminium sulphate. Various iron salts can also be used and would enable considerable economies in chemical costs to be achieved in steelworks. The percentage of aluminium oxide in aluminium sulphate varies according to its purity and the physical character of the coagulant. It has a comparatively limited range of *p*H value in which complete precipitation of the added aluminium is obtained usually as aluminium hydroxide. For the waters with which the paper is particularly concerned, this range of *p*H is between 5·0 and 6·5, although in harder waters it is generally between 6·0 and 6·7 *p*H. The commercial varieties are:

(i) Alumino-ferric: usually obtained in 50-lb. blocks containing 14–15% of aluminium oxide

(ii) Kibbled alumina: usually supplied in the form of broken chips 1½–2 in. in size. This is generally more convenient to store and handle than the blocks, and contains 15–16% of aluminium oxide

(iii) Granulated or powdered aluminium sulphate containing 16–18% of aluminium oxide; it is always used where dry feeding as distinct from solution feed is installed.

At normal temperatures the solubility of aluminium sulphate is up to 7¼ lb. of aluminium sulphate per gallon of solution. This saturated solution has a Twaddell hydrometer reading of 66, *i.e.*, a specific gravity of 1·33.

Iron Salts

The use of iron salts for coagulation is increasing, and for many industrial purification plants the use of such a coagulant offers many advantages apart from cost. In general, iron salts produce a heavier and denser floc over a wider *p*H range. This range extends both above and below that usually found best for aluminium sulphate. Often the use of iron salts may require the use of lime or other alkalis to give complete precipitation. Furthermore, they have the disadvantage of requiring more expensive solution tanks and dosage equipment. In general, a somewhat greater degree of control of treatment is needed.

Obviously, the first choice would be copperas (ferrous sulphate). The commercial variety is usually obtained in small broken lumps or as light-green crystals containing 29% or more of iron oxide. The crystalline sulphate is soluble in water at the rate of 4·6 lb./gal. at 50° F. or 6·2 lb./gal. at 20° F. These quantities are equivalent to 2·1 lb. and 2·6 lb., respectively, of the anhydrous salt. At present ferrous sulphate is finding its main application in connection with the lime or lime-soda precipitation softening and in the treatment of industrial wastes.

A very effective coagulant produced from copperas is known as chlorinated copperas; when ferrous sulphate is used in conjunction with chlorine it becomes converted into a mixture of ferric chloride and ferric sulphate when the ratio of chlorine to ferrous sulphate is not less than 1 part of chlorine to 7·8 parts of ferrous sulphate. In practice 1 part of chlorine to 7·2 parts of ferrous sulphate is required. This chlorinated copperas is a very effective coagulant with many applications and offers the opportunity of combining prechlorination with coagulation. The other iron salts, such as ferric chloride and ferric sulphate, have not found any large-scale application owing to their corrosive characters and cost.

Chlorinated copperas and alum work well together; in fact, on occasion the two together give better results than either used alone. In comparing aluminium and iron salts, generally speaking the plant results are the same, but the cost of iron coagulation is considerably less than that for alum alone.

The following are tentative specifications for ferrous sulphate for water treatment.*

Ferrous sulphate can be supplied in either of two forms, *i.e.*, as copperas or in the granular form known as sugar sulphate of iron. The granular material should have 90% passing a No. 10 standard sieve

* *Journal of the American Water Works Association*, 1950, vol. 42, p. 976.

having 9·21 openings per linear inch; 100% should pass a No. 4 standard sieve having 4·22 openings per linear inch. The lump copperas should preferably be ¾–3 in. The granular material should be clean and free from all dirt and particles of foreign matter. Both the granular and the lump ferrous sulphate should contain:

(i) Not more than 1% of matter insoluble in 1% sulphuric acid
(ii) Not less than 19·5% of available iron
(iii) Not more than 0·04% of free sulphuric acid expressed as H_2SO_4.

Sodium Aluminate

Most waters can be successfully coagulated with one or other of the reagents mentioned, but improved results can often be obtained at no extra cost, and often at a reduced cost, by the use of certain other chemicals known as auxiliary coagulants, of which sodium aluminate is the outstanding example. In contrast to aluminium sulphate, sodium aluminate is a white alkaline powder freely soluble in water, producing an alkaline solution. In general it is found that a dose of sodium aluminate of 5–10% of the alum dose, if added about 1 min. before the aluminium sulphate, gives excellent results. On no account should these two reagents be mixed in the same container. The advantage of sodium aluminate is that it makes the coagulant active over a wider range of *p*H, and it often produces a denser and tougher floc and at the same time a greater degree of clarification. The use of sodium aluminate often gives less residual alumina in the filtered water. Sodium aluminate contains about 54% of aluminium oxide, *i.e.*, about four times as much as aluminium sulphate.

Activated or Modified Silica

In a paper on the large-scale application of silica sols in water treatment, Baylis* demonstrated that the addition of sulphuric acid to a dilute solution of sodium silicate after proper ageing and further dilution could improve alum coagulation. As early as 1884 Graham had added weak hydrochloric acid to water-glass to form silica sol; he is generally credited with introducing the terms sol, gel, and peptization. The process involves the reaction of a suitable grade of sodium silicate containing 28–30% of silica with an acidic material such as a mineral acid, ammonium sulphate, chlorine, sodium bicarbonate, or even alum itself, so as partially to neutralize the alkalinity of sodium silicate. The dilute solution containing about 1·5–2·0% of silica is then aged for 1½–2 hr. and eventually at the end of this period is diluted to 0·6–1·0% of silica (SiO_2). At this level the silica sol is stable for 2–3 days without gelling. If, however, the stronger solutions are allowed to age for too long a period, gelation occurs and a strong jelly is formed.

In another process a 1% solution of aluminium sulphate is added to a 1% silicate solution in the ratio of 4 parts of alum to 1 part of silicate, and the mixture is used immediately as a coagulant aid. This is commonly referred to as the Graf–Schworm process.

Thus the term ' activated silica,' or as some prefer to call it, ' modified silica,' designates a negatively charged colloidal particle, and the micelles in activated silica are probably particles varying in size from 0·1 to 1·0 mμ. In practice it has been found that the ageing period for activated silica sols should be 10–50% of the actual time necessary for gel formation; if 25% of the actual time for gel formation is allowed good results are obtained.

In the earlier days activated silica sols were always prepared by the batch process, but today a large number of plants have installed continuous production and feed. This consists of adding predetermined amounts of dilute sodium silicate and the activating agent continuously to a mixing tank which often also acts as an ageing tank, and then immediately diluting the aged sol for addition to the water to be treated. The stronger the solutions of silicate and activant are, the shorter is the gelling time, and consequently the ageing period is a matter of minutes and not of hours. In one plant in Ireland 4% solutions of sodium bicarbonate and sodium silicate are used.

One of the great advantages of activated silica is that it lessens very appreciably the time necessary for floc formation at low temperatures and greatly decreases after precipitation of alum. A reduction in overall chemical costs is usually shown by its use. A reduction in wash-water is obtained with longer filter runs, and the quality of the filtered water is often improved. In using these sols it is important to keep to a flexible installation, because very marked differences in results are often obtained according to whether the sol is added before or after the main coagulant. For turbidity removal it is generally found that the sol added first is the better; the reverse is the case if colour removal is the main necessity. These activated silica sols have proved markedly effective in the case of lime or lime-soda precipitation softeners when on occasion they have completely replaced other coagulants, such as aluminium and iron sulphates.

Other Reagents

The coagulants and coagulant aids are perhaps from one point of view the main chemicals used in water treatment; space does not permit a detailed survey of the other water-treatment chemicals such as chlorine, the various alkalis, lime, soda ash, caustic soda, and the reagents used for special purposes, such as ozone, the various sodium phosphates, activated carbon (both granular and powdered), and many others.

MODERN TREATMENT PRACTICE

The main advances in chemical treatment have been in connection with the use of chemicals and better understanding of the chemistry of coagulation, since the properly designed and operated modern filtration plant gives a much higher efficiency from chemical treatment.

At one time it was considered sufficient if the coagulating chemicals were thoroughly mixed with the water to be treated, but in modern plants the water, after adequate mixing with the various coagulants, is given a further period of 15–30 min. slow stirring or flocculation. This permits the building-up of a dense granular floc before the water enters the

* J. R. Baylis, *Journal of the American Water Works Association*, 1937, vol. 29, p. 1355.

sedimentation tank proper; in many plants of the sludge-blanket or sludge-recirculation type the rapid mixing, flocculation, and sedimentation are combined in the same vessel.

If very turbid river waters containing large amounts of fairly coarse mineral matter have to be treated, a period of pre-settlement, as mentioned in the section on raw-water storage, is a great advantage, because by this means it is possible to effect an appreciable saving in chemicals and to lighten the load on the sedimentation tank itself. The accent in modern plants is very largely on preparing the water before it enters the filters, because without such proper coagulation and preparation the best designed and operated filter will not always give a satisfactory effluent. A correctly designed sedimentation tank plays a very large part in the satisfactory operation of any water-treatment plant, resulting not only in longer filter runs but also in a saving in chemical costs. The sludging of sedimentation tanks is important and should be carried out at regular intervals, because failure to do so often results in decomposition of the sludge, to the detriment of the water passing through the tank. The average sedimentation time allowed in normal horizontal or vertical flow tanks is 3 hr., but with the modern sludge-recirculation and sludge-blanket types of plant 1½–2 hr. seems to be ample.

The filter can rightly be regarded as the heart of any purification plant, because any failure of the filter is inevitably fraught with serious consequences. The usual filter media consist of sand, gravel, and pebbles, although on occasion advantages are claimed for the use of suitably graded anthracite. The rating of the filter as measured in gal./sq. ft./hr. should be related to the choice of medium and the quality of the filtrate required. If biological purification is required from a filter, the rating must be kept low and prechlorination must be avoided.

The indications that a filter has reached the end of its effective run and is in need of washing are usually either that the loss of head has reached a definite (usually pre-set) limit of 6–8 ft., or that the colour or turbidity of the filtrate has increased beyond the acceptable minimum. This may come on slowly with certain types of water, but with others, generally where the floc is fragile, as is often the case with the softer waters, colour or turbidity will in a very few minutes become very distinct. When this is the case, much can often be done to overcome it by paying more attention to coagulation or to the settlement side of the plant. It will be found convenient and helpful, especially where several filters are in use, to establish a definite rotation of washing; otherwise two or more filters of a battery may near the end of their run together, so that not only will the output be considerably reduced but also an unduly heavy load will be placed on the remainder of the filters. Under such conditions it is not possible to maintain a good mixed effluent.

So long as the plant has been designed and operated correctly through the previous stages, the result should be a clear, relatively bright, water suitable for most mill purposes, except, of course, where softening is required. However, even assuming that this quality has been obtained, the water may prove to be very corrosive, firstly, because the addition of the coagulants has reduced the *p*H value, producing a certain amount of free carbon dioxide, or secondly, because the original water was already on the acid side of neutrality. The corrosive tendency of a water is usually corrected after filtration by the addition of lime or other alkali, and with hard waters it is generally found sufficient to raise the *p*H value to 7·2–7·4, but softer waters will require the *p*H value to be increased to at least 7·8, and on occasion even higher values may be necessary. For most waters no further treatment will be required, but if the finished water is to be stored for any length of time, especially in an open clear-water reservoir, some form of sterilization, preferably by means of chlorine, is strongly recommended.

PLANT CONTROL

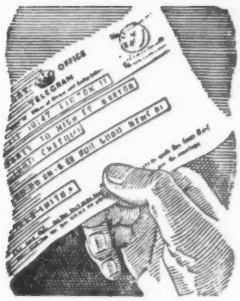
The ordinary analytical methods applicable to waters can only be carried out by skilled chemists in a laboratory, but today many tests have been greatly simplified, usually by reducing them to colorimetric estimations, and the time required to arrive at results sufficiently accurate for practical purposes has been greatly reduced. Consequently, many of the tests are now so simple that they can and should be made part of the duties of the plant attendant. The supervision and control of a water-treatment plant must be considered an essential because there are many very well-designed plants on which there is a tendency for the experienced but untrained operator to use nothing but the roughest of tests, often unrecorded. The additional expenditure used in providing apparatus for simple control tests and/or possibly in paying a somewhat higher wage to an attendant skilled enough to profit by the tests will be well justified, especially when it is borne in mind that any falling-off in the quality of the effluent from the treatment plant may involve the works in considerable waste of material and consequently of money. In every plant a daily log sheet should be kept, which should at least include:

Gallons of water pumped
Chemicals used
Filters washed
Hours since last washing
Raw water: *p*H value, turbidity, colour, alkalinity
Filtered water: *p*H value, turbidity, colour, alkalinity, residual chlorine if used.

The advantage of keeping even such a simple record is that it helps the operator to maintain interest and will eventually lead him to make comparisons and references as to the effect of varying chemical treatment on various types of water, so that it cannot do otherwise than improve plant efficiency.

Space has only permitted the briefest mention of many factors playing a part in running and controlling a water-treatment plant, but at the present time the standard of water-treatment equipment in the U.K. is so high that, provided that adequate plant has been installed, there is no reason why even the most unpromising sources of water should not be converted into a satisfactory and suitable supply for all purposes in iron and steelworks.

N E W S



ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1954

The **Annual General Meeting** of The Iron and Steel Institute will be held at 4 Grosvenor Gardens, London, S.W.1, on **Wednesday and Thursday, 26th and 27th May, 1954.** The Annual Dinner will be held on the evening of 26th May. Details of the programme will be given in a later issue of the *Journal*.

Special Meeting in Sweden, 1954

A special meeting of The Iron and Steel Institute will be held in Sweden from **5th to 9th June, 1954.** Details of the programme were given in the February issue of the *Journal*, p. 217.

Symposium on Powder Metallurgy

The Iron and Steel Institute is organizing a second **Symposium on Powder Metallurgy,** to be held in London on **Wednesday and Thursday, 1st and 2nd December, 1954.** Further details of the programme will be given in later issues of the *Journal*.

Société des Ingenieurs Civils de France

A joint meeting of The Iron and Steel Institute and the British Section of the Société des Ingenieurs Civils de France has been arranged for the presentation of a paper on "*The Ugine-Sejournet Process for the Hot Extrusion of Steel*," by Monsieur Sejournet. The meeting will be held at 4 Grosvenor Gardens, London, S.W.1, on Thursday, 1st April, 1954, commencing at 6.0 P.M. Tea will be served at 5.30 P.M. and all Members are invited to attend.

Staff

Mr. J. P. Saville, hitherto Assistant Information Officer, has been appointed Information Officer with effect from 1st January, 1954.

NEWS OF MEMBERS

▶ Mr. J. V. CHATTERTON has left Radiation Ltd. to join the Special Projects Department of Cincinatti Milling Machines Ltd., Birmingham.

▶ Mr. E. F. FARRINGTON has been appointed Assistant to the Chief Engineer, Appleby-Frodingham Steel Company.

▶ Mr. B. S. FOWLER has left Richard Thomas and Baldwins Ltd., and has joined Ashmore, Benson, Pease and Co., Ltd.

▶ Mr. L. GASKELL has been appointed Chief Engineer of the Appleby-Frodingham Steel Company.

▶ Mr. E. GREGORY has taken up an appointment with the Manganese, Bronze and Brass Co., Ltd., Ipswich.

▶ Dr. J. W. JENKIN has been elected a Fellow of the Royal Institute of Chemistry.

▶ Mr. W. D. PARRY has left the Loewy Engineering Co., Ltd., to join the East Moors Works of Guest Keen Baldwins Iron and Steel Co., Ltd.

▶ Mr. J. A. REAVELL, Chairman of the Kestner Evaporator and Engineering Co., Ltd., is paying a three months' visit to South Africa and Southern Rhodesia.

▶ Mr. G. E. ROBINSON has been appointed Sales Manager of the Foundry and Engineering Division of the Brightside Foundry and Engineering Co., Ltd.

▶ Mr. E. G. SPOONER has left India to return to the U.K.

▶ Mr. G. M. TAYLOR has taken up an appointment with the Drayton Regulator and Instrument Co., Ltd.

▶ Mr. D. THOMAS has left the British Iron and Steel Research Association to take up an appointment with the Park Gate Iron and Steel Co., Ltd.

▶ Mr. W. K. L. THOMAS has been awarded the degree of M.Sc. of the University of London and the Diploma of Imperial College. He has now left the U.K. for Tanganyika, where he has joined the Department of Geological Survey.

▶ Mr. P. C. THORNTON has left the Plessey Co., Ltd., to take up the appointment of Lecturer in the Department of Metallurgy, Battersea Polytechnic.

▶ Mr. E. V. TULL has been awarded the degree of M.Sc. (Met.) of the University College of Swansea.

Obituary

Mr. T. H. BURNHAM of the Case Development Co., Ltd.

Mr. A. DOUGLAS, of Glasgow, on 21st June, 1953.

Mr. E. J. FOX, late Managing Director of the Stanton Ironworks, Nottingham, on 18th January, 1954. Mr. Fox was elected a Member of The Iron and Steel Institute in 1912. He became a Member of Council in 1936, and was made an Honorary Vice-President in 1945.

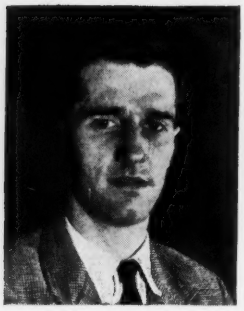
Mr. J. T. WRIGHT, of Hagley, near Stourbridge, on 1st January, 1954.

CONTRIBUTORS TO THE JOURNAL

B. B. Bach, B.Sc., A.R.I.C.—Research investigator with the British Cast Iron Research Association.

Mr. Bach was born in 1922, and was educated at King's Norton Grammar School, Birmingham. He received his technical education at the Birmingham College of Technology and as an external student of London University, and was awarded the degree of B.Sc. with 2nd Class Honours in Special Chemistry in 1946. He was made an A.R.I.C. in the same year. His first post was with Foundry Services Ltd., where he worked as an analyst. He took up his present appointment in 1945, and is in charge of research on gases in cast iron.

B. B. Bach



J. V. Dawson

L. W. L. Smith

W. P. C. Ungoed

J. V. Dawson—Research investigator with the British Cast Iron Research Association.

Mr. Dawson was born in 1927, and was educated at Bromsgrove County High School and at the Birmingham College of Technology. He joined the B.C.I.R.A. as an apprentice in 1944, and was appointed to the Gases Section of the Research Department three years later.

L. W. L. Smith, B.Sc.—Research investigator with the British Cast Iron Research Association.

Mr. Smith was born in 1925, and was educated at Handsworth Grammar School, Birmingham, and at Birmingham University, where he graduated in Chemistry in 1946. He then joined Albright and Wilson Ltd. as an analyst, a position which he held until he joined the B.C.I.R.A. as a research chemist in 1949. He became a member of the staff of the Gases section of the Research Department three years ago.

W. P. C. Ungoed, Assoc.I.E.E., M.Inst.F.—Power Plant Superintendent, Steel Company of Wales Ltd., Port Talbot.

Mr. Ungoed received his technical education at Swansea Technical College and the University College of Swansea. After an apprenticeship with the B.T.-H. Co., Ltd., he joined the staff of Messrs. Balfour Beatty, serving at Llanelly, Spondon, and Warwick Power Stations. He was then appointed to Tir John Power Station, Swansea, where he became Assistant Boiler House Superintendent. In 1944 he held the position of Honorary Lecturer in Fuel Technology at the University. A year later he became Boiler House Engineer at Fulham Power Station, a position which he held for two years until he was appointed Assistant Power Station Superintendent H.P. and L.P. Power Stations, Ocker Hill. He took up his present appointment in 1948.

IRON AND STEEL ENGINEERS GROUP

The **Twenty-Fifth Meeting** of the Iron and Steel Engineers Group will be held at 4 Grosvenor Gardens, London, S.W.1, on **Thursday, 18th March, 1954.** A Buffet Luncheon will be held in the Library.

The following is the detailed programme:

10.30 A.M.–12.45 P.M.—Discussion on:

"*Treatment of Water for the Iron and Steel Industry*," by A. J. Lamb and A. H. Waddington (Paterson Engineering Co., Ltd.) (*see* this issue, pp. 283–291).

12.45–2.0 P.M.—Buffet Luncheon.

2.0–4.0 P.M.—Discussion on:

"*Modern Industrial Boiler Plant*," by W. P. C. Ungoed (Steel Company of Wales Ltd.) (*see* this issue, pp. 291–302).

An invitation has been accepted to hold a meeting of the Engineers Group in **Newcastle and Consett from 13th to 16th September, 1954.** It is intended that the meeting will include discussion of papers on the development of Consett Works, and visits to the Consett Works and the iron ore wharves on the Tyne.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Staff Changes

Dr. J. PEARSON, Head of the Chemistry Department, has in addition been appointed temporary Head of the Steelmaking Division, in succession to Dr. A. H. LECKIE. At Swansea, Mr. D. LUTHER PHILLIPS has retired from his position as Head of the South Wales Laboratories, although he is still connected with B.I.S.R.A. in a consultative capacity. He has been succeeded by Mr. S. S. CARLISLE, who was formerly Head of the Instruments Section of the Physics Department.

AFFILIATED LOCAL SOCIETIES

Sheffield Metallurgical Association

Mr. F. H. Saniter, Director of Research of the Research and Development Department of the United Stee Companies, Ltd., and a Member of Council of The Iron and Steel Institute, was installed as President of the Sheffield Metallurgical Association for the Session 1954–55 on 26th January, 1954. In his Presidential Address Mr. Saniter spoke on "*The Post-war Expansion of the United Steel Companies' Research and Development Department.*" His speech included details of the organization of the Department and of its relationship with other branches of the Company; he also mentioned the co-operation maintained with research associations and with other firms in the industry.

NEWS OF SCIENCE AND INDUSTRY

Mond Nickel Fellowships

The Mond Nickel Fellowships Committee invites applications for the award of Mond Nickel Fellowships for 1954. Awards will be made to selected applicants of British nationality, educated to University degree or similar standard, although not necessarily qualified in metallurgy, who wish to undergo a programme of training in industrial establishments: they will normally take the form of travelling Fellowships—awards for training at Universities may be made in special circumstances. There are no age limits, though awards will seldom be given to persons over 35 years of age. Each Fellowship will occupy one full working year. The Committee hope to award up to five Fellowships each year, of an average value of £900 to £1200 each.

Mond Nickel Fellowships will be awarded in furtherance of the following objects:

(*a*) To allow selected persons to pursue such training as will make them better capable of applying the results of research to the problems and processes of the British metallurgical and metal-using industries.

(*b*) To increase the number of persons who, if they are subsequently employed in executive and administrative positions in the British metallurgical and metal-using industries, will be competent to appreciate the technological significance of research and its results.

(*c*) To assist persons with qualifications in metallurgy to obtain additional training helpful in enabling them ultimately to assume executive and administrative positions in British metallurgical and metal-using industries.

(*d*) To provide training facilities whereby persons qualified in Sciences other than Metallurgy may be attracted into the metallurgical field and may help to alleviate the shortage of qualified metallurgists available to industry.

Applicants will be required to state the programme of training in respect of which they are applying for an award, as well as particulars of their education, qualifications, and previous career. Full particulars and forms of application can be obtained from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Completed application forms will be required to reach the Secretary of the Committee not later than 1st June, 1954.

N.P.L. : Symposium on Creep and Fracture of Metals

The Metallurgy Division of the National Physical Laboratory is organizing a Symposium on "*Creep and Fracture of Metals (A Review of Recent Theoretical Progress)*," to be held at Teddington on **31st May–1st June, 1954.** Further details of the Symposium will be given in a later issue of the *Journal*.

Conference on Defects in Crystalline Solids (Bristol)

The H. H. Wills Physical Laboratory of the University of Bristol, in conjunction with the International Union of Pure and Applied Physics and the Institute of Physics, will hold a Conference on Defects in Crystalline Solids in Bristol, on **13th–17th July, 1954.** The Conference will be particularly concerned with defects such as vacancies and F-centres, resonance methods of investigating their properties, and the way in which they react with dislocations. Dislocations will thus be discussed in their chemical aspects, as influencing diffusion and precipitation in the solid state, rather than in relation to plastic flow.

Conference on Mechanical Effects on Dislocations in Crystals (Birmingham)

The Department of Metallurgy of the University of Birmingham have arranged a Conference on the Mechanical Effects of Dislocations in Crystals, to be held in Birmingham on **19th–20th July, 1954.** The Conference will be concerned with recent advances in the knowledge of the effects of dislocations on mechanical properties of metals, and particular attention will be paid to effects due to moving dislocations in both metals and non-metals, and to the nucleation and dynamics of slip in metals. It will thus be complementary to the Conference to be held by the University of Bristol on 13th–17th July, which will consider the chemical aspects of dislocations in crystals. Both these Conferences follow the Meeting of the International Union of Physics.

International Union of Crystallography (Paris)

The 3rd General Assembly and International Congress of the International Union of Crystallography will be held in Paris from **21st to 28th July, 1954.** Papers on all aspects of crystallographic research will be presented, and there will also be an exhibition of crystallographic apparatus and books. After the Congress, two specialized Symposia will be held on "*The Location and Function of Hydrogen*" and "*The Mechanism of Phase Transitions in Crystals.*" Visits will also be made to places of mineralogical interest. Full details of the Congress are given in the First Circular, copies of which are obtainable from the General Secretary of the Union, Mr. R. C. Evans, Crystallographic Laboratory, Cavendish Laboratory, Cambridge.

Insignia Award in Technology

The Insignia Award in Technology was established by the Council of the City and Guilds of London Institute about a year ago to provide a high qualification for persons in industry whose initial training was based primarily upon practical experience combined with theoretical study and who, having gained appropriate City and Guilds' certificates as craftsmen or technicians, have now advanced in their industry by a combination of progressive experience and further study. A candidate upon whom 'The City and Guilds of London Institute's Insignia Award in Technology' is conferred will receive a Warrant specifying the section of industry and the branch of technology in which his knowledge and skill are recognized, and under the Institute's Royal Charter he will be authorized to use the insignia letters 'C.G.I.A.' A register of Insignia Awards will be maintained by the Institute.

Candidates must be at least 30 years of age and be sponsored by three referees of appropriate standing. They must have been apprenticed or otherwise suitably trained and have had a minimum of seven years' progressive experience in their industry, and must hold relevant Full Technological Certificates of the Institute. Theses submitted must be of some 10,000 to 20,000 words, and must show that the candidate is acquainted with the current practice and problems of his industry at 'technological' level. If his thesis is reported upon satisfactorily by the Assessor appointed by the Institute, the candidate is required to appear for interview before an *ad hoc* Panel nominated by the Institute. The Insignia Award Committee, on the recommendation of the Panel, will then make its final decision as to the Award, subject to ratification by the Council of the Institute. There is no special time-table involved in the scheme, and each candidate is considered as a separate 'case,' great care being taken to help him at all stages of his candidature.

Candidates are considered in terms of five broad industrial groups, namely chemical, constructional, electrical, mechanical, and textile industries. A strong Committee includes two representatives from each of these sections of industry, together with co-opted members. The Committee thus offers a collective guarantee to industry that the standards of the Award will be kept at a level consonant with the high aims and purpose of the Council. Considerable formal and informal contact has been established with a number of professional and industrial bodies and with responsible individual members of industry, who have helped in enlisting the aid of experts in the rôle of external Assessors and members of the interviewing Panels.

The wide range of topics and the standard and level of treatment dealt with in the candidates' theses may be valuable contributions to technological practice and discussion. The Insignia Award Committee is therefore considering a scheme whereby a precis of successful papers may be made available to all who are interested and, in exceptional cases, where guidance may be given to ensure full publication.

A first list of recipients of the Award cannot yet be issued, but candidates' theses are now being received and considered. The Council have, however, in each of the five industrial groups, made up to three Foundation Awards to distinguished representatives of industry, who have gained City and Guilds' Certificates. These were formally presented by the Duke of Edinburgh as the President of the Institute, at its last Yearly Meeting.

A copy of the Regulations governing the Award, together with Notes for the Guidance of Candidates, may be obtained on application to the Director, Department of Technology (I.A.), City and Guilds of London Institute, 31 Brechin Place, London, S.W.7.

Fortiweld

Experiments made by the United Steel Companies Ltd. to determine the effects of boron on the properties of low-carbon molybdenum steel have led to the discovery of a new steel, which has been given the name of 'Fortiweld.' This new steel has a tensile strength of 40 tons/sq. in., and because of its low carbon content is easily weldable; it also possesses good properties at 450–500° C. It is therefore particularly suitable for highly stressed welded structures at ordinary or elevated temperatures, and it has already been used with success in many fields, including the casings of aircraft jet engines, special tubing, and bridge components.

Epping Auto-Shunter

F. E. Wetherill Ltd. have been appointed main distributors for Great Britain and all territories overseas for the 'Epping Auto-Shunter.'

Industrial Publication Received

"*Top of the Shop!*"—a review of productivity in the valves industry—British Productivity Council (Price 2*s.*).

Change of Address

The Cardiff Office of THOS. FIRTH AND JOHN BROWN LTD. has removed to 46 Park Place, Cardiff. (Tel.: Cardiff 27922).

DIARY

1st Mar.—CLEVELAND INSTITUTION OF ENGINEERS—"*Some Starting Up and Operating Experiences at the Abbey Melting Shop of the Steel Company of Wales Ltd.*," by A. J. Kesterton—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 P.M.

2nd Mar.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Aspects of Optical and Electron Microscopy*," by J. Nutting and G. C. Smith—B.I.S.R.A., Hoyle Street, Sheffield, 7.0 P.M.

4th Mar.—EAST MIDLANDS METALLURGICAL SOCIETY—"*Experimental Welding of Metallurgical and Engineering Interest*," by B. R. Byrne—Nottingham and District Technical College, Shakespeare Street, Nottingham, 7.30 P.M.

5th Mar.—SOCIETY OF CHEMICAL INDUSTRY (Corrosion Group)—"*Protective Coatings for Ships and Marine Installations*," by J. C. Hudson; "*Cathodic Protection of Ships and Jetties*," by K. A. Spencer; "*Corrosion of Ships' Machinery*," by L. Kenworthy; and "*Performance of Aluminium Alloys in Ships*," by D. C. G. Lees—Royal Technical College, George Street, Glasgow, C.1, 2.30 P.M. and 7.15 P.M.

8th Mar.—JUNIOR INSTITUTION OF ENGINEERS (Sheffield and District Section)—"*The Use of High-Frequency Heating in the Metallurgical Industry*," by J. B. Ingall—Livesey Clegg House, Sheffield, 7.30 P.M.

9th Mar.—SHEFFIELD METALLURGICAL ASSOCIATION—Biennial Dinner—Royal Victoria Station Hotel, Sheffield, 7.30 P.M.

10th Mar.—NEWPORT AND DISTRICT METALLURGICAL SOCIETY—"*Some Metallurgical Problems Arising in Welding*," by W. K. B. Marshall—Whitehead Institute, Cardiff Road, Newport, 7.0 P.M.

10th Mar.—INSTITUTION OF CHEMICAL ENGINEERS (Midlands Branch)—"*Design of Pressure Vessels and the Mechanism of Failure in Service*," by A. H. Goodger—The University, Edmund Street, Birmingham, 6.30 P.M.

11th Mar.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Bulk Oxygen in Steelworks*," by F. Clark and J. L. Harrison—Victoria Hotel, Wolverhampton, 7.30 P.M.

11th Mar.—LIVERPOOL METALLURGICAL SOCIETY—"*Titanium—a Metal of Engineering Importance?*" by P. L. Teed—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, 7.0 P.M.

15th Mar.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS (Joint meeting with the Institute of Metals)—"*Some Factors affecting Spring Design*," by W. R. Berry—University Building, St. George's Square, Sheffield, 7.30 P.M.

16th Mar.—SHEFFIELD METALLURGICAL ASSOCIATION (Joint meeting with the Refractories Association of Great Britain and the Institute of Clay Technology)—"*Dr. Mellor—His Life and Work*," by A. T. Green—Grand Hotel, Sheffield, 7.30 P.M.

16th Mar.—NORTH EAST METALLURGICAL SOCIETY—"*Some Factors Influencing Basic Open-Hearth Productivity*," by T. F. Pearson—Cleveland Scientific and Technical Institution, Middlesbrough, 7.15 P.M.

17th Mar.—STAFFORDSHIRE IRON AND STEEL INSTITUTE (Associates' Section)—"*Roll Making*," by K. H. Wright—Training Centre, Stewarts and Lloyds, Ltd., Bilston, 7.30 P.M.

18th Mar.—IRON AND STEEL ENGINEERS GROUP—Twenty-Fifth Meeting—"*Treatment of Water for the Iron and Steel Industry*," by A. J. Lamb and A. H. Waddington, and "*Modern Industrial Boiler Plant*," by W. P. C. Ungoed—4 Grosvenor Gardens, London, S.W.1, 10.30 A.M.

18th Mar.—LIVERPOOL METALLURGICAL SOCIETY—Conversazione—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, 7.0 P.M.

23rd Mar.—LINCOLNSHIRE IRON AND STEEL INSTITUTE—Annual General Meeting—"*Development of the use of Coal/Coke Oven Gas and Pitch, Creosote at Appleby-Frodingham*," by W. Jackson—Wortley Hotel, Scunthorpe, 7.0 P.M.

25th Mar.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Metallurgical Problems in Stratospheric Flight*," by P. L. Teed—Star and Garter Hotel, Wolverhampton, 7.30 P.M.

30th Mar.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Brittle Fracture*," by T. S. Robertson—B.I.S.R.A. Hoyle Street, Sheffield, 7.0 P.M.

TRANSLATION SERVICE

(The previous announcement was made in the February, 1954, issue of the *Journal*, p. 220).

TRANSLATIONS IN COURSE OF PREPARATION

(German). K. BUNGARDT: "The Development of Heat-Resisting Steels with High Strength at Elevated Temperatures." (*Stahl und Eisen*, 1953, vol. 73, Nov. 5, pp. 1496–1503).

(German). G. KOWARSCH: "Experiences with Ingot-Mould Varnishes." (*Stahl und Eisen*, 1953, vol. 73, Dec. 3, pp. 1654–1656).

ABSTRACTS AND BOOK NOTICES

IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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MINERAL RESOURCES

The Styrian Ore Mine—The Deposits and the Present State of the Workings. B. Vogl. (*Glückauf*, 1953, **89**, Sept., 937–951). The postwar development of the Styrian iron ore deposits, which include a high degree of mechanization, is discussed in detail.—L. D. H.

Fifth Empire Mining and Metallurgical Congress, Australia and New Zealand, 1953. This Congress was held in Australia from April 12 to May 23, 1953, and the proceedings were published in 1953 in six volumes by the Australasian Institute of Mining and Metallurgy. The first volume entitled "Geology of Australian Ore Deposits" contains the following papers of interest to the steel industry:

The Mineral Resources of Australia. H. G. Raggatt. (3–40). A general survey of the known deposits of minerals in Australia, including iron ore, coal, tungsten, molybdenum, chromium, cobalt, and nickel, is given.

Tectonic Setting of Australian Ore Deposits. E. S. Hills. (41–61).

Banded Iron Formations in Western Australia. K. R. Miles. (159–171). Economically valuable concentrations of iron ore in Western Australia are limited in number; these are discussed. Manganese oxides are associated with hydrated iron oxides but none of these deposits is capable of more than small scale exploitation.

Koolyanobbing Iron Ore. K. R. Miles. (172–176). The geology of this deposit, which is one of the most important deposits in Western Australia is described.

Horseshoe Manganese Deposits, Peak Hill Goldfield. H. A. Ellis. (245–250). Details of this deposit are given. It consists of a number of scattered deposits of manganese dioxide and limonite which are being worked.

Coobina Chromite Deposits. R. S. Matheson. (251–253). Large reserves of chromite occur at Coobina but high transport charges would make it difficult to compete with foreign chromite on the open market.

Iron Ore Deposits of Yampi Sound, W.A. F. Canavan. (276–283). Large deposits of iron ore (hematite) are found in this district in the north of Western Australia. The deposit on Cockatoo Island has been worked since 1950. The estimated reserves on this island are over 18·5 million tons and the ore contains about 98% Fe_2O_3. Reserves on Koolan Island are estimated at over 54 million tons.

Geology of Cloncurry District. S. R. L. Shepherd. (384–390). Among other deposits, cobalt and iron are found in this area of Queensland but are not now being worked.

Iron Ores of the Middleback Ranges, South Australia. E. A. Rudd and K. R. Miles. (449–463). A description of these extensive deposits of high grade iron ore is given. The total production of iron ore from them was 46·5 million tons up to 1951 and production for the year ending June 1951 was 2,378,000 tons.

Mineralogy of the Middleback Iron Ores. A. B. Edwards. (464–472). A detailed examination of the principal minerals found in this deposit is made. The iron ores are essentially hematites and have an iron content of from 63 to 68% with sulphur 0·05 to 0·07% and phosphorus 0·02 to 0·05%.

Other Iron Ore Occurrences in South Australia. R. L. Jack. (473–475). The iron ore deposits in South Australia other than those of Middleback are numerous but small. Details of them are given. Only two appear to be capable of producing more than half a million tons and only three more than 300,000 tons.

Chromite Deposits of the Marlborough-Princhester-Tungamull District. J. E. Ridgway. (845–849). These deposits of chromite in central Queensland are discussed. The district has been well prospected and the smallness of the deposits emphasizes the country's deficiency with regard to chromite.—B. G. B.

The Ore Deposits of Newfoundland. K. E. Dittmann. (*Stahl u. Eisen*, 1953, **73**, Sept. 24, 1284–1288). The climatic, economic, and transport conditions of the country are described. In addition to the mining of copper, zinc, and lead, the exploitation of the Wabana iron ore deposits is of special importance. The reserves, mining methods, and use of this ore are discussed.—J. P.

Fluorspar Deposits of Burro Mountains and Vicinity, New Mexico. E. Gillerman. (*U.S. Geol. Survey, Bull.* 973–F., 1952).

Dolomite Deposit near Sloan, Nevada. C. Deiss. (*U.S. Geol. Survey, Bull.* 973–C, 1952).

Preliminary Report on the Bedded Manganese of the Lake Mead Region Nevada and Arizona. V. E. McKelvey, J. H. Wiese, and V. H. Johnson. (*U.S. Geol. Survey, Bull.* 948–D, 1949).

Manganese Deposits of Western Utah. M. D. Crittenden, jun. (*U.S. Geol. Survey, Bull.* 979–A, 1951).

The Cle Elum River Nickeliferous Iron Deposits, Kittitas County, Washington. C. A. Lamey and P. E. Hotz. (*U.S. Geol. Survey, Bull.* 978–B, 1952).

The Chief Mineral Resourses of the State of Rio Grande do Sul. P. de Castro Nogueira. (*Rev. de Quim. Indust.*, 1953, **22**, May, 14–19). [In Portuguese]. The author surveys the

geology of the state of Rio Grande do Sul and reviews the non-metallic resources, including fuels, sands, clays, and ores. The iron ore is considered to be insufficient to support an important iron and steel industry.—R. S.

Geologic Reconnaissance of the Mineral Deposits of Thailand. G. F. Brown, S. Buravas, J. Charaljavanaphet, N. Jalichandra, W. D. Johnton, jun., V. Sresthaputra, and G. C. Taylor, jun. (U.S. Geol. Survey Bull. 984, 1951). A survey in 1949–50 ascertained that iron ore occurs in many widely distributed laterites and in several contact-metamorphic deposits. The largest known deposit at Khao Thap Khwai contains an estimated reserve of about 720,000 tons of ore ranging between 48 and 66% Fe. On the island of Ko Kram there are about 5500 tons of ore containing about 25% Mn and 15% Fe, minable by hand breaking and sorting.—R. A. R.

Notes on Geology and Mineralization in Fiji. J. F. A. Taylor. (*Proc. Australasian Inst. Min. Met.*, 1953, Mar.–June, 1–11). There has been much prospecting for manganese in the last three years and many small deposits have been located.—R. A. R.

Iron Ores, the Basic Material of the Metallurgical Industry. J. Bertin-Roulleau. (*Mét. Constr. Mécan.*, 1953, **85,** Mar., 225). A short account is presented of the known iron ore deposits of the world.—B. G. B.

ORES—MINING AND TREATMENT

Fifth Empire Mining and Metallurgical Congress, Australia and New Zealand, 1953. This Congress was held in Australia from April 12 to May 23, 1953, and the proceedings were published in 1953 in six volumes by the Australasian Institute of Mining and Metallurgy. The third and fifth volumes entitled "Ore Dressing Methods in Australia and Adjacent Territories" and "Australian Mining and Metallurgy—Miscellaneous Features and Practices" respectively, contain the following chapters of interest to the steel industry :

Treatment of Other Metallic Ores and Industrial Minerals. H. H. Dunkin. (**3,** 275–317). The methods of transporting and preparing the ore adopted by Broken Hill Proprietary Co., Ltd., and Australian Iron and Steel Ltd. are described.—R. A. R.

Hygiene in the Metalliferous Mining Industry of Australia. G. Day. (**5,** 54–86). The precautions adopted by the Broken Hill Proprietary Co. Ltd., and by Australian Iron and Steel Ltd. to combat silicosis ; poisoning by benzol, lead, carbon monoxide and manganese ; and dermatitis ; are outlined.

Safety Practices in the Australian Mining and Metallurgical Industries. H. G. Thomas. (**3,** 87–119). The author gives a short account of safety work in two important Australian iron and steel works.

Education and Training, A—The Education of Mining and Metallurgical Engineers in Australia. H. K. Worner. (**5,** 165–189).

A Survey of Mining and Metallurgical Research Activities in the Commonwealth of Australia. J. N. Greenwood. (**5,** 211–253).

Trolley Changeover Increases Ore Bridge Capacity. A. L. Williams. (*Iron Steel Eng.*, 1953, **30,** Sept., 194–197). A description is given of a redesigned trolley to operate on an old but structurally sound ore bridge. The new trolley handles a 12-ton bucket in place of the old 7½-ton bucket. Considerable use was made of aluminium and alloy steel to reduce its weight.—M. D. J. B.

Discharging Iron Ore. R. T. Eddison and D. G. Owen. (Operational Research Quarterly, 1953, **5,** Sept., 39–50). A review is presented of the operation of importing iron ore from overseas dock-side to home dock-side, the paper being confined to explaining the objectives of the research, describing the main problems, and the general conclusions.—R. A. R.

The Rôle of Temperature in Rotating Furnaces. P. A. Helmbold. (*Chim. et Ind.*, 1953, **70,** Oct., 672–676). The problem of heat exchange between gas and product in the shaft of a furnace is discussed in relation to the heat and temperature requirements of such processes as calcining and evaporation. Factors which must be controlled to obtain a regular product are considered, namely, the irregularity of feeding material, moisture content, uneven fuel supply or furnace rotation, and air leaks.—A. G.

Thermal Efficiency and Waste Gas Temperature of Shaft Lime Kilns Fired with Blast-Furnace Gas. H. Eigen. (*Radex Rundschau*, 1952, (7), Dec., 293–298). The thermal efficiency of lime kilns fired with blast-furnace gas is assessed in detail, using theoretical data and figures from operational practice. Comparison with coke-fired kilns shows the latter to be superior in respect of fuel cost and overheads per ton of lime produced. Coke-fired kilns show a thermal efficiency of about 80% against less than 62% for gas-fired kilns.—E. C.

FUEL—PREPARATION, PROPERTIES, AND USES

A Comprehensive Combustion Diagram. A. Dumez. (*Usine Nouvelle*, 1953, **9,** Spring Issue. 117–120). From a knowledge of two of the three factors CO_2 plus SO_2, oxygen, and carbon monoxide, all combustion characteristics can be determined. To simplify the necessary calculations a special diagram has been developed and its construction and use are explained with examples.—A. G.

The Economics of Fuel in Iron Making. M. Sýkora. (*Hutnik* (Prague), 1953, **3,** (7–8), 185–187). [In Czech]. The utilization and calorific value of solid and gaseous fuels involved in iron-making are discussed.—P. F.

Eddies in Turbulent Jet Diffusion Flames. M. W. Thring. (*Nature*, 1953, **172,** Oct. 3, 634–635). The study of flames in which a high velocity jet of fuel entrains its own combustion air is possible with cold models. Results indicate a smooth time average pattern of mixing in contrast with high-speed photography of a flame which reveals large-scale eddies.—A. G.

The Length of Oil and Gas Flames: Extension of Free-Flame Relationships to Practical Conditions. A. L. Cude. (*J. Iron Steel Inst.*, 1954, **176,** Mar., 270–273). [This issue].

A New Dense-Medium Recovery and Cleaning System: The Tromp Coal Washing Plant at Williamthorpe Colliery. A. G. Smith. (*Trans. Inst. Min. Eng.*, 1953, **113,** Nov., 191–206).

Fifth Empire Mining and Metallurgical Congress, Australia and New Zealand, 1953. This Congress was held in Australia from April 12 to May 23, 1953, and the proceedings were published in 1953 in six volumes by the Australasian Institute of Mining and Metallurgy. In volume VI entitled "Coal in Australia" the following papers of interest to the iron and steel industry appeared :

Some Notes on the Chemical Characteristics and Coking Properties of Some New South Wales Coal Seams. H. R. Brown and H. Berry. (Pp. 93–125). A description is given of the more important coal seams in New South Wales which are at present being mined or are likely to be mined in the near future. In general, the coal appears in thick seams (15–50 in.), has a high inherent ash content which is difficult to remove and has a low sulphur content. Details of the properties of a wide range of coals are given in tabular form.

Coal Preparation in New South Wales. C. W. Miller and R. L. Carr. (Pp. 187–252). A comprehensive account of the methods used for coal preparation at a number of coal mines in New South Wales is presented.—B. G. B.

Coal Crushing in Coke-Oven Plants. H. Gauze. (*Hutník* (Poland), 1953, **20,** (9), 285–288). [In Polish]. The coal used in Polish coke-oven plants is harder than in other countries, and foreign grinding equipment often failed to produce the necessary screen analysis. Bearing this in mind, crushing equipment in Polish coke-oven plants is critically surveyed and the re-equipment necessary for the production of high quality coke is discussed.—V. G.

Heating Coke-Oven Batteries. E. Ryszka. (*Prace Instytutow Ministerstwa Hutnictwa*, 1953, **5,** (3), 162–171). [In Polish]. The author discusses the results of his own observations, made during the starting up of six coke-oven batteries. The author describes the properties of the silica bricks and their crystallographic transformations. On the basis of these data a heating-rate schedule is drawn up. The methods of measuring temperature, expansion, and contraction are dealt with.—Y. G.

Metallurgical Coke Making Practice. R. L. Carr. *See* p. 310.

The Manufacture of 'Iron Coke' from Ore Fines and Gas Coal. H. Barking and C. Eymann. (*Glückauf*, 1953, **89,** Sept. 26, 993–1003). The influence of ore additions on the properties of the coke is first described in detail ; the manufacture by normal coke-oven practice is said to present no difficulties, and the resulting coke and by-products compare favourably with the normal products. Material and heat balances are worked out in detail.—L. D. H.

The Fissuring of Coke. A. F. Boyer, A. Ladam, and J.-L. Soulê. (*Rev. Ind. Min.*, 1953, **34**, Aug., 592–615). An experimental and theoretical study of the mechanism of fissuring, and the differences between gas and coking coals is reported. The occurrence of fissures, depends on (*a*) the form of the contraction curve after resolidification, and (*b*) the mechanical strength of the coke between 500° and 700° C. The more important factor is (*a*). This in turn depends on the resolidification temperature.—A. G.

Combustion Experiments with Coke Dust. H. Winter and R. Jüterbock. (*B.W.K.*, 1953, **5**, Sept., 297–303). Details of long-time full-scale experiments on the use of coke dust as fuel for industrial boilers are given. It is shown that with suitable burners, even coarse high-ash coke can be used with advantage. The choice of refractory materials for the combustion chamber and its design are discussed.—P. F.

Gas at the Donawitz Steelworks. A. Vacek. (*Maschinenbau u. Wärmewirt.*, 1953, **8**, May, 122–126). An account is given of the modernization of the Donawitz steelworks, in particular the means adopted to offset the low calorific value of the gas due to the use of carbonate ores. Oxygen enrichment is described, and a summary is given of a process of producing gas from lignite.—L. D. H.

The Problem of Nitrogen Peroxide in Coke-Oven Gas—Disadvantages, Origin, Elimination, and Determination. J. Pierrain. (*Chim. et Ind.*, 1953, **70**, Aug., 189–196).

TEMPERATURE MEASUREMENT AND CONTROL

A New Means for Temperature Measurements and Gas Analysis. J. Lundeberg. (*Trans. Instruments and Measurements Conf.*, Stockholm, 1952, 400–410). [In English]. A kinematic thermometer is described, based on the conception of the measurement of pressure changes in a constant flow of air between two nozzles at different temperatures. For the nozzles are substituted a constant capacity pump, with a hydraulic amplifier, and a series of capillary tube elements to cover various pressure ranges. The principle, development, and present construction of the instrument are described, as well as a modification used for continuous gas analysis, based on changes of pressure consequent on the absorption of the gas being investigated.—L. D. H.

Movable Thermocouple for Enclosed Spaces. R. Kh. Burshtein. (*Zavodskaya Laboratoriya*, 1950, **16**, (8), 1021–1022). [In Russian]. A design of a thermocouple and sheath, moved by a magnet, is described which permits temperatures to be measured at various points in an enclosed space.—S. K.

Modified 1913 Reference Tables for Iron-Constantan Thermocouples. R. J. Corruccini and H. Shenker. (*J. Res. Nat. Bur. Stand.*, 1953, **50**, May, 229–248). An investigation was made of the characteristics of iron-constantan thermocouples. Using the calibration of the thermocouple that most nearly matched the 1913 reference table, a slightly different temp./e.m.f. relationship was derived which is more nearly realizable by commercially available materials. The new relationship is presented in four mutually consistent tables covering the range −196 to +871° C.—R. A. R.

The Heating of Metallic Surfaces by Friction. W. Späth. (*Metalloberfläche*, 1953, **7**, July, A104–A109). The mechanism of heat production by friction between metallic surfaces is described. Direct thermoelectric measurement of the temperature is difficult because of the thermoelectrically inactive film of metal produced at the bearing surface. Measurements of temperatures produced by machining and wire drawing are described, and finally, the thermoelectric compensating effects produced at a bearing surface are discussed.—L. D. H.

REFRACTORY MATERIALS

Ceramics—A Symposium. (Brit. Ceramic Soc., 1953). This 877-page volume, arranged and edited by A. T. Green and G. H. Stewart, contains the papers presented when the British Ceramic Society celebrated its Jubilee at Stoke-on Trent and Buxton in 1950. Abstracts of papers of interest to the steel industry follow :

Geology and Ceramics. P. S. Keeling. (1–14). In the section on raw materials for refractories the author discusses in general terms the origin and properties of alumina, chrome ore, dolomite, fireclay, magnesite, olivine and serpentine, silica rock, and the sillimanite group.

Structural Aspects of the Mineralogy of Clays and Related Silicates. G. W. Brindley and D. M. C. MacEwan. (15–59).

The Colloidal and Rheological Properties of Clay. D. A. Holdridge. (60–93).

Phase Relationships in Ceramics. J. White. (94–162).

X-Rays and Ceramics. H. M. Richardson. (163–185).

The Action of Heat on Clays. J. F. Hyslop. (186–200).

The Forms of Silica. A. E. Dodd. (201–211).

Fireclay and Alumino-Silicate Refractories in the 20th Century. F. H. Clews. (418–447).

The Manufacture of Silica Bricks During the Last Fifty Years. T. R. Lynam. (448–473).

Raw Materials for the Manufacture of Basic Refractories. A. E. Dodd. (474–487).

The Spinels and Their Relation to Chrome Ores. G. R. Rigby. (488–512).

The Development of Chrome-Magnesite Bricks. H. Parnham. (513–535).

Super-Refractories. W. A. Archibald and E. J. D. Smith. (536–591).

The Development of Insulating Bricks for Furnace Construction. H. Oliver. (592–636).

Progress in the Development of Refractories for Steel Manufacture. J. H. Chesters. (637–650).

Progress in the Development of Blast-Furnace Refractories. J. Mackenzie. (651–670).

Progress in the Development of Blast-Furnace Refractories. J. Mackenzie. (651–670).

The Thermal Products of Ceramic Products. J. F. Clements, (687–725).

Testing Refractory Materials. J. F. Clements. (726–737).

Full Use is Made of Mechanization in Manufacture of Silica Refractories. (*Blast Furn. Steel Plant*, 1953, **41**, Oct., 1187–1192). A description of the new plant at Windham, Ohio, of Harbison-Walker for the manufacture of Star and Vega brands of silica bricks (ordinary and super-duty qualities respectively) is given.—B. G. B.

Refractories for the Ferrous Metallurgical Industry in Australia. D. M. Humby. *See* p.311.

The Importance of the Types of Stress for Assessing the Performance of Basic Furnace Linings. L. Hütter. (*Radex Rundschau*, 1953, (2), Feb., 66–85). The stresses to which basic refractories are subjected in open-hearth furnaces are considered individually and with regard to their cumulative effect. Differences in physical properties of various refractories are discussed and the necessity for appropriate selection of material for each location is stressed. Thermal and thermochemical effects, including recrystallization phenomena, are discussed. The dependence of roof and lining performance on all such factors is pointed out and some examples are analysed in detail.—E. C.

The Measurement of Thermal Conductivity of Refractory Materials. F. H. Norton and W. D. Kingery. (*U.S. Atomic Energy Commission Technical Information Service*, NYO–602, Apr. 1, 1952). A report is presented of the measurement by the ellipsoid envelope method of the thermal conductivities of titania, mullite, and zircon in the 200–1400° C. range.

Study of the Pyrolysis of Dolomite in Dry Nitrogen and Carbon Dioxide, with Linearly Increasing Temperature. A. Richer and P. Vallet. (*Rev. Mét.*, 1953, **50**, Sept., 597–602). Using a thermobalance, the effects of composition, state of division, weight of sample, heating rate, and atmosphere on the pyrolysis of dolomite have been studied. The atmosphere influences both the mode and temperature range of decomposition. $MgCO_3$, and $CaCO_3$, decompose simultaneously in dry nitrogen, whereas in carbon dioxide $MgCO_3$ dissociates completely first.—A. G.

Some Factors Affecting the Crushing Strength of Porous Refractory Bodies. J. F. Clements and G. R. Rigby. (*Trans. Brit. Ceram. Soc.*, 1953, **52**, Oct., 565–577). An investigation on the influence of firing temperature on the crushing strength of porous refractory bodies is reported. For fireclay, no appreciable difference in strength was detected between materials of equal density that had been fired at different temperatures. Over the normal range of water content there was no connection between the crushing strength after firing, and the water content of the mixture.—D. L. C. P.

Chemical Notes on Chrome-Magnesite. J. F. Hyslop. (*Trans. Brit. Ceram. Soc.*, 1953, **52**, Oct., 554–560). Information on the constitution, the resistance to reduction, the iron-oxide/chromite growth reaction, and slagging of chrome-

magnesite refractories is surveyed, and the results of some experiments, with chemical analyses, are given.—D. L. C. P.

Contribution to the Hardness Testing of Magnesite Crystals. P. Grodzinski. (*Radex Rundschau*, 1953, (1), Jan., 3–8). Results are quoted of microhardness tests carried out on samples of Austrian magnesite with a double cone diamond indenter developed by the Industrial Diamond Information Bureau. A Meyer analysis proved possible and the indenter is claimed to be superior to the Vickers diamond pyramid.

The Analysis of Chromite-Bearing Basic Refractories. N. Skalla and E. Thoma. (*Radex Rundschau*, 1953, (3), Mar., 129–130). Concise instructions are given for the Chemical analysis of chrome-magnesite bricks by customary methods. The necessity for fine grinding of the sample is emphasized to ensure correct quantities of chromite ore and sintered magnesia.—E. C.

Measurement of Equilibrium Pressures of Magnesite. E. Cremer and K. Allgeuer. (*Radex Rundschau*, 1953, (2), Feb., 54–57). The measurement of the pressure of CO_2 evolved on heating magnesite is described. The final pressure is found to be independent of the duration of heating. The dissociation temperature was determined as 323° C. Small quantities of CO were detected. The dissociation was found to be irreversible.—E. C.

Refractory Products and Their Utilization. L. Halm. (*Usine Nouvelle*, 1953, **9**, Spring Issue, 49–56). The different grades of refractory have been classified by A.F.N.O.R. (French Standards Association) as follows : (*a*) Silica products with $SiO_2 > 91\%$ and $Al_2O_3 < 3\%$ for steelworks and coke ovens ; (*b*) siliceous products with SiO_2 between 85 and 95% and $Al_2O_3 > 5\%$ for coke ovens and cupolas; and (*c*) clay-base products. Modern methods of manufacture, including vacuum extrusion, have eliminated the need for additions of clay as a plasticizer in high-grade refractories. Properties and methods of testing refractories are described and the correct choice of refractories for blast-furnace linings, cowper stoves, iron ladles, and open-hearth furnaces is discussed.

Lining Electric Furnaces with a Combination of Brick Shapes. (*Radex Rundschau*, 1952, (7), Dec., 303–304). Combinations of standard rectangular bricks and only one type of shaped brick are recommended for electric furnace linings to achieve economy and simplicity of stock requirements. Any desired furnace diameter can be made up and a table quotes brick quantities.—E. C.

Materials for Open-Hearth Furnace Bottoms. F. Procháska. (*Hutník* (Prague), 1953, **3**, (7–8), 171–173). [In Czech]. Czechoslovak and Soviet standards relating to acid and basic materials for open-hearth furnace bottoms are given and discussed.—P. F.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Coke Saving in the Blast-Furnace by Charge Preparation. O. Hajíček. (*Hutník* (Prague), 1953, **3**, (9), 206–209). [In Czech]. Major advances leading to a reduced coke rate are surveyed. The need for high iron content in charges is emphasized as 1% less iron in the burden leads to a 3% decrease in blast-furnace efficiency according to Soviet data. The principles and advantages of enriching lean iron ores in sloping rotary furnaces are discussed, and methods of preparing the charge and of charging blast-furnaces for optimum performance are described.—P. F.

Survey of the Structural Evolution of the Low Shaft Blast-Furnace. N. Sjögren. (*Radex Rundschau*, 1953, (3), Mar., 95–105). The background and history of development of the low-shaft furnace are outlined, and the principles of low-shaft furnace practice are explained. Several recent large scale experiments with various furnace designs and techniques are described. The Office of European Economic Co-operation project at Liége is dealt with but operational data or results are not quoted.—E. C.

The Experimental Low Shaft Furnace at Ougrée. (*Usine Nouvelle*, 1953, **9**, May 28, 22–23). The development of the furnace to study the smelting of fine ores is outlined. Oxygen enrichment was suggested, permitting the use of low-grade fuel and yielding a richer gas. Disadvantages include the supply of oxygen and the need for burden preparation. Details of international organization, progress to date and the general programme of trials are given.—A. G.

The Manufacturer of Iron in the Electric Furnace and Work Carried Out in Spain. (*J. Four Elect.*, 1952 **61**, July–Aug., 111–113 ; Sept.–Oct., 137–138 ; Nov.–Dec., 169–174 ; 1953, **62**, Mar.–Apr., 51–52 ; May–June, 87–88). A description is given of trials which have been carried out in Spain to produce iron from local ores by reduction in electric furnaces. The majority of furnaces used were designed for the production of ferro-alloys and the modifications carried out are explained. The results obtained are discussed. Trouble was encountered due to excessive electrode consumption. Graphitic electrodes were more suitable than those of amorphous carbon. Söderberg electrodes 400 mm. in dia. gave good performances.

On the Reduction Equilibrium Diagram of Iron Oxide. K. Sanbongi. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1953, **A, 5,** Feb., 53–62). [In English]. In previous work on the Fe–C–O system, the equilibrium constants for the systems Fe_3O_4–liquid-oxide–CO/CO_2 gas and wüstite–liquid oxide–CO-CO_2 gas, and the relation between oxygen percentage and CO-CO_2 gas were not known ; portions of the diagram were therefore tentative. These have been corrected in the light of recent results by Darken and Gurry, and Takeuchi and Igaki, and a diagram for the system Fe–H–O has also been drawn up.

Apparatus for Measuring Electromotive Forces between Metal Oxides at High Temperatures and Investigations on the FeO–Al_2O_3 System at 1500° C. W. A. Fischer and R. Schäfer. (*Arch. Eisenhüttenwesen*, 1953, **24**, July-Aug., 307–314). Equipment is described in which two platinum electrodes are embedded in a sintered block of metal oxides ; with this the e.m.f. and resistances between the two can be measured at temperatures up to 1500° C. The block is heated in a carbon-tube furnaces in an atmosphere of argon. The block was a composite ; one platinum electrode was embedded in pure corundum and the other in a mixture of corundum and various proportions of ferrous oxide. When both parts of the block were of corundum, no e.m.f. was detected between the electrodes but as soon as FeO was added to one part, an e.m.f. was recorded. This increased gradually with time and reached a maximum and approximately constant value after about 6 hr. The maximum value depended on the FeO content ; it increased rapidly as the FeO was raised to 1%, then increased slowly up to 40% of FeO, and rose rapidly again between 45 and 50%, thereafter remaining essentially constant. It is assumed that this behaviour was due to the initial formation of the spinel hercynite (FeO. Al_2O_3), the measured e.m.f. being that of the cell Pt/FeO. Al_2O_3/Al_2O_3/Pt, followed by the formation of Al_2O_3-saturated FeO when the content of the latter exceeded that required to form the spinel. When the content of FeO was above 45%, there were signs of melting and diffusion of the FeO from the mixture into the pure Al_2O_3, whereas when the FeO content was below 45% there was no melting or diffusion. This suggests that the m.p. of hercynite is above 1500° C. ; it had been reported previously as approx. 1440° C. The melting point was re-determined and found to lie above 1650° C., although it decreased if the compound became oxidized.—J. .P

Operational Research. Sir Charles Goodeve. (*J. Inst. Prod. Eng.*, 1953, **32,** Sept., 387–393). The use and application of operational research methods to improve industrial efficiency is described. Among examples which are considered are the cost of pig-iron production and the operation of hot metal furnaces.—B. G. B.

Fifth Empire Mining and Metallurgical Congress, Australia and New Zealand, 1953. This Congress was held in Australia from April 12 to May 23, 1953, and the proceedings were published in 1953 in six volumes by the Australasian Institute of Mining and Metallurgy. Volume IVA, entitled "Extractive Metallurgy in Australia—Ferrous Metallurgy" contains the following chapters of interest to the steel industry :

Metallurgical Coke Making Practice. R. L. Carr. (1–26). An account of the coking coal deposits and of the development of the Australian metallurgical coke-making practice is given. Full details of the present plant and practice at Newcastle and at Port Kembla in New South Wales are given.

Blast-Furnace Practice in Australasia. C. Newman. (27–66). An historical account of the development of Australian and New Zealand blast-furnace practice is first presented. Blast-furnaces are at present operating only in Australia and are situated at the coastal centres of New-

castle, Port Kembla, and Whyalla. The main plants at Newcastle and Port Kembla produce principally basic iron (800,000 and 1,248,000 tons/year respectively) and that at Whyalla foundry iron (219,000 tons/year). Details of the furnaces, plant layout and practice are given.

Steel Making Practice—Mass Production Steels. R. L. Knight. (67–106). A comprehensive account of the steelmaking practice at Newcastle and Port Kembla in Australia is given with details of the open-hearth furnace design and operation. Australia's capacity to produce steel is at present 2·5 million tons/year.

Steel Making Practice—Special Steels. E. G. Smith. (107–128). Extensions in 1940 to the plant of the Commonwealth Steel Co. Ltd., Waratah, New South Wales, have made a complete range of alloy, tool, stainless, and heat-resisting steels available in Australia. Details of the plant layout and practice are given. Both arc and H.F. furnaces are used.

Iron and Steel Foundry Practice. G. Brown. (129–146). A detailed description of Australian foundries and the type of work they carry out is given. There are 391 foundries in Australia and they can produce practically all the castings required in grey iron, malleable iron and steel with the exception of a very few large steel castings.

Steel Rolling Mill Practice in Australia. M. R. Pitt. (147–170). A complete survey of Australian Steel rolling mill practice is made. Details of the location, type of mill, number of stands, roll size and products of 39 rolling mills are given. A tinplate plant incorporating hot dipped or electrolytic tinning lines is projected.

Heavy Forging Practice. F. A. Hamilton. (171–180). The heavy forging practice in Australia is reviewed. Details of 13 forging presses are given. The tendency in Australia is to follow the standard British practice and relatively little upset work is carried out. The normal methods of inspection are used.

Ferro-Alloy Practice. R. T. Hooper. (181–194). The large proportion of Australian supplies of a wide range of ferro-alloys are produced at a new plant erected in 1940 within the steelworks at Newcastle. Details of the method used to produce ferrosilicon, manganese alloys, chromium alloys, and alloys of iron with tungsten, molybdenum, vanadium, titanium, niobium plus tantalum, phosphorus, and silicon plus zirconium are given. Considerable improvements in the design of electric furnaces have been made.

The Charcoal-Iron Industry at Wundowie, Western Australia. A. C. Harris. (195–199). The plant at Wundowie is situated near large deposits of limonite iron ore and is surrounded by 300,000 acres of low-grade jarrah wood forest. It is a pilot plant to test the possibility of founding a much larger industry. A small blast-furnace (hearth 5 ft. in dia.) is producing 35–40 tons of iron per day (mainly containing 1·5–4% Si). A low slag volume (450–600 lb./ton of iron) is made possible by the low ash content of the charcoal.

Refractories for the Ferrous Metallurgical Industry in Australia. D. M. Humby. (200–217). The production of silica, alumino-silicates and basic refractories in Australia is described.—B. G. B.

PRODUCTION OF STEEL

Recent Researches in the American Iron and Steel Industry. G. C. Bain. (*Rev. Mét.*, 1953, **50,** Aug., 521–536). Theoretical studies dealing with diffusion in metals, structural hardening, internal friction, recrystallization, and austenite decomposition are discussed and a bibliography of recent work in these fields is given. The main efforts is in the domain of applied research. An experimental coke oven has been used to determine the best means of utilizing inferior grades of coking coals. The use of oxygen is only considered to be of interest in ferromanganese production. Trials with all basic open-hearth furnaces are continuing. Furnaces with suspended basic roofs give good results and make higher temperatures possible. Tests are in progress on the use of gas-oxygen flames to keep ingot heads liquid during teeming. The addition of rare earth metals improves the hot plasticity of certain high-alloy stainless steels. Research on taconite concentration continues.—A. G.

Movement of the Metal in the Converter and the Nitrogen Content of the Steel. K. Daeves. (*Stahl u. Eisen*, 1953, **73,** Sept. 24, 1280–1282). Model experiments have shown that if the height of metal in a converter is too great in relation to the width of the ring between the outer tuyeres and the converter wall, a state of unstable movement occurs. The whole mass of metal is permeated by gas bubbles and increased nitrogen pick-up results. Below the critical ratio of height to ring width (0·75), stable flow results. The air then flows upwards mainly in the central region of the bath and a large stable air-free vortex of metal is formed over the above-mentioned ring. In this vortex refining is indirect, *i.e.*, is brought about by iron oxides in the metal ; the nitrogen content at the end of the blow is thus small. Side-blowing of a converter also results in indirect refining and produces low nitrogen steel.—J. P.

Movement Phenomena in the Converter. F. Schultz-Grunow. (*Stahl u. Eisen*, 1953, **73,** Sept. 24, 1282–1284). The movement in a blown converter has been studied by means of a model. Stable blowing occurs when the height of the bath is less than three-quarters of the width of the ring between the outer tuyeres and the converter wall. An iron-air mixture rises as a central column, separates at the surface of the bath and the iron then moves across the surface, down the walls and back to the central column. When the height of the metal exceeds the critical value, there is no central column and the metal-air mixture oscillates and slops over the side of the converter.—J. P.

Lining and Bottom of the Basic Converters at Stewarts and Lloyds, Corby. D. Bird. (*Stahl u. Eisen*, 1953, **73,** Oct. 8, 1337–1338 ; *Iron Coal Trades Rev.*, 1953, **167,** Oct. 9, 845–848). Efforts have been made at Corby in recent years to increase the life of the converter linings, to improve steel quality and to raise production. The original normal rammed tar-dolomite mixture has been replaced in the lower part of the converter by General Refractories Ltd. '341' dolomite bricks, and the life of the lining has been increased from 196 to 265 heats.—J. P.

Investigations on the Quality of Tar for Converter Bottoms. R. Calaque. (*Stahl u. Eisen*, 1953, **73,** Oct. 8, 1339). A recipe is given for a special tar for mixing with dolomite for converter bottoms (as used at Homécourt) which gives a product of constant and durable character. This appreciably increases the life of bottoms.—J. P.

Experiences with Vibrators. W. Köhler. (*Stahl u. Eisen*, 1953, **73,** Oct. 8, 1340–1341). Results obtained by increasing the power of a vibrator for consolidating the bottoms of converters are discussed. An insufficient number of campaigns has been carried out to assess accurately the value of the method, but the few results indicate that consolidation by vibration of even 2·4 m. bottoms is satisfactory.—J. P.

A New Ramming Machine for the Preparation of Converter Bottoms. K. E. Mayer. (*Stahl u. Eisen*, 1953, **73,** Oct. 8, 1341–1342). The construction and operation of the Bamag ramming machine is described. Although it has not been in use for a long enough period to determine the best method of operation, the lives of converter bottoms made with it are 15–20% greater than those made with the former Versen machine.—J. P.

A Systematic Study, Using the Volume Rate Meter, of the Factors Governing the Blowability of a Basic-Bessemer Charge. P. Leroy, M. Gombert, and B. Trentini. (*Rev. Mét.*, 1953, **50,** June, 433–444 ; July 500–520 ; Aug., 579–595 ; Sept., 642–664). A consideration of the process reveals that the time-independent variable is the volume blown up to a given instant rather than the blowing pressure or time of conversion. With the aid of the flowmeter described earlier, the influence of the following factors on the blowability of a converter charge was investigated : (*a*) Liquid iron composition ; (*b*) quantity and size grading of solid additions ; (*c*) temperature of the iron charged ; (*d*) lining wear ; (*e*) weight of iron charged and its relation to blowing time and nitrogen content of the finished steel ; (*f*) dead zones or 'zones of circulation,' an annular dead zone being the most harmful ; (*g*) the total area and number of orifices employed ; (*h*) quality of the limestone employed (including the degree of roasting, quantity of fines, and reactivity) ; and (*i*) permeability, studied first in a single tuyere and an empty converter and finally, in a charged converter. Finally, the factors governing the quantity of air needed to refine a ton of basic iron are considered.—A. G.

The Speed of Heating-Up Basic Open-Hearth Furnaces. (*Radex Rundschau*, 1953, (1), Jan., 36–38). Principles of heating-up are discussed in relation to thermal properties of various lining materials. All-basic linings are stated to permit the highest heating-up rates. Graphs showing limiting speeds of heating-up for various types of linings are discussed.—E. C.

Firing Open Hearth-Furnaces with Natural Gas. F. Bartu. (*Radex Rundschau*, 1953, (3), Mar., 110–116). The composition of natural gas from various sources is outlined and the high heating value of American gases due to the presence of heavy hydrocarbons is emphasized. The principles and thermal conditions of gas firing open-hearth furnaces are discussed, both for autocarburation using cracked CH_4, and carburation with tar or oil. Suitable designs of gas ports and burners are described.—E. C.

Suspended Stack Openings and Slag Pocket Roofs. F. Bartu. (*Radex Rundschau*, 1953, (2), Feb., 86–91). Details are described and discussed of methods of suspension from steel sections which take the load and asymetric stresses off the open-hearth furnace walls, thus increasing furnace life and reducing time off for repairs. The suspended construction involves the use of metal-clad ferroclip bricks.—E. C.

Steel Making Practice—Mass Production Steels. R. L. Knight. *See* p. 311.

Steel Making Practice—Special Steels. E. H. Smith. *See* p. 311.

Oxygen Activity in Iron Oxide Slags. H. Larson and J. Chipman. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197**: *J. Met.*, 1953, **5**, Sept., 1089–1096). The authors have studied the equilibrium betsween slags containing rion oxide and gases consisting of air or CO/CO_2 mixtures, and have established the value of the ratio $Fe^{++}/(Fe^{+++}+Fe^{++})$ for a range of oxygen pressures from 10^{-2} to 10^{-9} atm. This ratio is increased by addition of basic oxides, and decreased by acid oxides. Oxygen activities at 1550° C. are shown graphically for conditions similar to those at the slag-gas interface in an open-hearth furnace.—G. F.

Some Characteristic Factors of Deoxidation Processes in the Production of Phosphorus Steels. A. L. Zagyanskii. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **91**, (6), 1369–1372). [In Russian]. Some theoretical problems in the deoxidation of liquid steels, particularly those connected with the use of ferromanganese-phosphorus, are discussed. The excellent deoxidizing properties of phosphorus combined with a better removal of non-metallic inclusions are stressed. It is also postulated that during deoxidation by manganese an isomorphic mixture of manganese and ferrous oxides is formed: $(m\text{Mn}, n\text{Fe})\text{O}$ or $(m\text{Fe}, n\text{Mn})\text{O}$, and therefore during dephosphorization the phosphates $(FeMn)_3(PO_4)_2$ and $(MnFe)_3(PO_4)_2$ are formed, which, being unstable and of a low specific gravity, float easily and enter the slag as the respective calcium phosphates.—V. G.

The Economic Use of Open-Hearth Alloy Steels in Place of Electric Furnace Steels. V. Keclík. (*Hutník* (Prague), 1953, **3**, (7–8), 162–168). [In Czech]. Methods and principles involved in making open-hearth alloy steels which are equivalent, or almost equivalent, to electric furnace steels are discussed, and an analysis is made of Russian data relating to the production and mechanical properties of equivalent open-hearth steels. Deoxidizing in basic furnaces is considered to be not yet quite satisfactory, and the further development of the Perrin process of deoxidizing is thought advisable.—P.F.

Determination of Arc Furnace Optimum Current. D. R. Cochran. (*Blast Furn. Steel Plant*, 1953, **41**, Sept., 1031–1036). A method for determining the optimum arc current at which to operate an arc furnace for making steel is described; any increase in the arc current above this value results in a decrease in the arc kilowatts.—B. G. B.

Automatic Control of Electrodes in Metallurgical Arc Furnaces. J. Perrin. (*J. Four Elect.*, 1953, **62**, Mar.-Apr., 53–56; May-June, 89–92). Modern equipment used for the control of electrodes is described in detail; a number of photographs of the equipment are reproduced. Details of the construction of the equipment are given. A number of examples of different methods of achieving automatic control of the electrodes which are used in electric furnaces for the manufacture of calcium carbide and ferro-alloys are described.

Manufacture of Semi-Killed Steel Ingots of Billet Size in the Electric Furnace. (*J. Four Elect.*, 1953, **62**, July-Aug., 117–119). The manufacture of ingots suitable for direct treatment in a rolling mill without the necessity for an intermediate blooming train, is described. The ingots vary between 30 and 120 kg. in weight and between 90 and 120 are made from each melt. One 10-ton electric furnace is able to give the same output as an open-hearth furnace of 25 to 30 tons capacity. Considerable financial saving results from this new technique owing to the elimination of a blooming mill and heating furnaces.—B. G. B.

Modernization and Productivity in the French Electrochemical and Electrometallurgical Industries. R. Sevin. (*J. Four Elect.*, 1953, **62**, May-June, 77–82). A brief account of the production of special alloy steels at the Aciéries Electriques d'Ugine is given, together with short descriptions of the manufacture of calcium and silicon carbides and aluminium in France.—B. G. B.

Experiences with Chromite Hearths in Electric Furnaces. (*J. Four Elect.*, 1952, **61**, Nov.-Dec., 171–172). The "Rustless" process for the manufacture of stainless steels in an electric furnace uses a chrome ore as a source of chromium with or without the addition of ferro-chromium carbide and conjointly with stainless steel scrap. In the process, the hearth of the furnace is lined with chromite bricks and has a life of about 800 melts on a 12 to 16-ton Heroult furnace and 1000 melts on a 25-ton furnace. Measurements show that the hearth temperature is of the order of 1780° C.—B. G. B.

The Technique of Melting and Casting under High Vacuum. O. Winkler. (*Stahl u. Eisen*, 1953, **73**, Sept. 24, 1261–1268). The advantages, particularly those of reduction of contamination by gaseous and slag inclusions, to be gained by producing steels under high vacuum are discussed, and the precautions to be taken when doing so are indicated. The procedure for conducting a melt in the Balzer's 25-kg. vacuum melting apparatus is briefly described.—J. P.

Induction Heated Melting and Holding Furnaces. E. Bertram. (*Giesserei*, 1953, **40**, Oct. 1, 527–533). A general comparison is made between resistance and induction heating. The various designs of the two main types of induction furnaces are then described and illustrated. The energy consumptions of the different electric furnaces are compared and the effect of working time on the total amount of power used is calculated. The numerous possibilities of low-frequency crucible furnaces are described.—R. J. W.

Melting Steel in a High-Frequency Induction Furnace. H. Bojanowski. (*Giesserei*, 1953, **40**, Oct. 1, 547–548). A brief description of the way in which an H.F. furnace works is given. The crucible materials are then considered and acid and basic linings are described.—R. J. W.

Heat Changes in Metallurgical Reactions. C. V. Schwarz. (*Arch. Eisenhüttenwesen*, 1953, **24**, July-Aug., 285–306). The heats of formation of metallurgically important compounds are given in tabular form with references to sources of data. The types of compounds dealt with are: Oxides, hydrides, carbides, nitrides, sulphides, phosphides, chlorides, fluorides, fluosilicates, cyanides, cyanamides, carbonates, carbonyls, hydroxides, phosphates, silicates, aluminates, borates, sulphates, nitrates, silicides, and intermetallic compounds. Also listed are heats of combustion of some hydrocarbons, and the heats of fusion, evaporation, and dissociation of a few gases.

Status Report On Continuous Casting. W. B. Pierce. (*Steel*, 1953, **133**, Oct. 12, 256–272). A report is presented on the experience gained by the Allegheny Ludlum Steel Corp. in continuously casting stainless steel sections in a pilot plant. The process has reached the stage of commercial machines being prepared for production in 1954. The present plant comprises a reservoir, refractory tundish, oscillating water-cooled mould, cooling sprays, withdrawing rolls, and cut-off torch. Subsequent rolling must reduce the section 4 to 1 to give desired physical properties. Grades of steel that have been cast are specified; most sections have been $3\frac{3}{4}$ in. square or $5\frac{1}{2}$ in. round. The method gives a yield 10% higher than casting in hot-topped ingot moulds and rolling. The first cost and manpower requirement of a commercial machine are quoted. Suggested specifications are: 150 sq. in. capacity, 120 in./min. casting speed, and up to 20 tons/hr. production, for a single strand caster.—D. L. C. P.

Defective Ingots—Their Causes and Prevention. A. Lincke. (*Met. u. Giessereitechnik*, 1952, **2**, Apr., 109–112). The causes of various defects found in ingots are examined and means of avoiding them discussed. In particular, the importance of correct temperature and speed of teeming are stressed, and recommendations for good practice are given. The possibility

of inhibiting oxide films, by mould coatings or by small additions of lead or bismuth, is discussed.—H. R. M.

PRODUCTION OF FERRO-ALLOYS

New Plant Makes Available Increased Supply of Alloys. C. Longenecker. (*Blast Furn. Steel Plant*, 1953, **41**, Oct., 1171–1175). A short description of the new Marietta plant of the Electro Metallurgical Co. in Ohio is given. The melting of ores and other raw materials takes place in large submerged-arc furnaces. The molten alloy is run off, cast into large flat slabs and crushed in a very large crushing and sizing unit. A new type of alloy called "Simplex Ferrochrome" is being produced and the manufacture of electrolytic chromium and manganese is projected.

Fundamental Researches on Metallurgical Treatment of Manganese Ores I. On the Equilibrium in the Reduction of Mn_3O_4 with CO. T. Isihara and A. Kigoshi. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1953, **A, 5**, Apr., 172–178). [In English]. These studies were designed to give data for the production of electrolytic manganese from low-grade ores. The equilibrium constant of the reaction $Mn_3O_4+CO=3MnO+CO_2$, and the effect of temperature on it and the free energy change, were determined for the range 500–800° C. Data on the dissociation equilibrium of Mn_3O_4 are also given. Thermodynamical relations between MnO and MnO_2 or Mn_2O_3 are determined indirectly . (11 references).—K. E. J.

Ferromanganese Cleaning Plant Starts up on Duquesne Furnace. (*Iron Steel Eng.*, 1953, **30**, Aug., 136–139). A new ferromanganese cleaning plant which will eliminate the heavy discharge of furnace and dust peculiar to ferromanganese blast-furnace operation is described. Five electrostatic precipitators with a combined capacity of 135,000 cu. ft./min. will be used to clean the gas.—M. D. J. B.

Ferro-Alloy Practice. R. J. Hooper. *See* p. 311.

FOUNDRY PRACTICE

Development of Commercial Vacuum Furnaces for Melting Metals and Alloys. J. H. Moore. (*Metal Progress*, 1953, **64**, Sept., 161–166). A number of different types of vacuum furnace which have been developed, are described. A modern furnace is considered in detail. It is capable of producing 1000-lb. ingots of alloys and 600-lb. ingots of steel and heat-resisting alloys. The pressure can be reduced to one micron.—B. G. B.

Iron and Steel Foundry Practice. G. Brown. *See* p. 311.

Heating the Blast for Cupolas. A. A. Shmelev. (*Liteinoe Proizvodstvo*, 1953, **3**, (1), 11–13). [In Russian]. Cupola practice with blast heating is described and discussed, results at two plants being compared. Methods used for modifying a 3-ton cupola to work with hot blast are illustrated. Graphs showing the effect on the rate of increase of cast iron temperature of changes in blast pressure are presented. The influence of recuperator design and methods of securing constant burning conditions of the exit gas are considered. Results of heat balances for controlled melts in two different cupolas show that the effect of blast heating increases with duration of operation and improvement in coke quality.—S. K.

The Use of Chrome Magnesite Refractories for Lining Cupolas. N. P. Nikolaichik, V. M. Chebotarev, D. E. Beletskii, and L. A. Aniukhina. (*Liteinoe Proizvodstvo*, 1953, **3**, (3), 18–19). [In Russian]. Experience in the use of different refractories for lining cupolas is briefly reviewed, and details are given of the use of chrome-magnesite brick with over 38% magnesia and 15–20% chromic oxide in the melting zone. The chrome-magnesite bricks were found to need repair, mainly directly above tuyeres, after operating for eight days. The normal firebricks usually lasted only two days. No changes occurred in the fluidities of iron or slag on changing to chrome-magnesite brick, nor in the temperature or composition of the iron in the runner. Changes in the composition of the slag are tabulated.—S. K.

Mechanization of Making Up the Charge and of Charging Cupolas with Skip Hoists. I. Z. Belostotskii and N. A. Strukov. (*Liteinoe Proizvodstvo*, 1953, **3**, (3), 15–18). [In Russian]. Mechanized methods for charging cupolas and making up the charge are compared, the rate of production for which each is best suited being considered.—S. K.

Oxygen and Nitrogen Content in Hematite Pig Iron and in Castings After Melting in Different Furnace Units. J. Willems and R. Opitz. (*Giesserei*, 1953, **40**, Oct. 1, 510–516). An investigation of the oxygen and nitrogen in pig iron, and in the types of cast iron made therefrom, show a decrease in the oxygen and an increase in the nitrogen in castings and *vice versa* with pig iron. Lower oxygen contents were obtained in pulverized-coal-fired horizontal furnaces than in cold blast cupolas. Hot blast cupolas yielded, in general, a more favourable value. A metallurgical evaluation of melts from a cupola is given, special reference being made to the oxygen and nitrogen contents. These are related to tapping temperature, silicon content of castings and oxygen in the slag. Measures necessary to obtain high quality castings are described and illustrated.—R. J. W.

Experiments with Hematite Pig Iron in Grey and Malleable Iron Foundries. C. W. Pfallenschmidt. (*Giesserei*, 1953, **40**, Oct. 1, 505–510). The economic use of pig iron in foundries is first considered. Statistics are given for the period 1913–1953 for the production of various types of pig iron in Germany. Investigations on the effect of gases, especially oxygen, on four different kinds of pig iron are described.

The Influence of the Condition of the Charge Material On Malleable Iron from a Cupola. H. Siegel. (*Giesserei*, 1953, **40**, Oct. 1, 516–527). An investigation is described in which the formation of the 'black spot' defect is related to the different forms of oxygen found in the liquid iron. Shrinkage-cavity tests show that these oxides influence the size of the these cavities and the volume of blow-holes. A clear relationship exists between the oxygen content of iron, the oxide content of the slag and the amount of rust on the scrap iron. The strength tests and chemical analyses are described.

Austrian Developments in the Production of High Strength Cast Iron. R. Mitsche and R. Weinberger. (*Radex Rundschau*, 1953, (1), Jan., 28–35). Possibilities of producing high strength cast iron were investigated by the Österreichische Studiengemeinschaft zur Entwicklung von mechanisch hochfestem Gusseisen, and their work is surveyed. Investigations were confined to production in the cupola furnace with subsequent treatment in the ladle. Methods of influencing graphite growth are discussed.—E. C.

Liquid Inoculation of Cast Iron. N. M. Varfolomeev and D. M. Gol'denberg. (*Liteinoe Proizvodstvo*, 1953, **3**, (3), 14). [In Russian]. In the method described for inoculating cast iron in the liquid state, an alloy containing 3·5% C, 9% Si and 0·7% Mn is prepared from 75% ferrosilicon and liquid grey cast iron and added to a ladle containing white iron. The white iron is at a temperature of 1300–1350° C., and 220 kg. of alloy are sufficient to inoculate 5500 kg. of iron, the assimilation of silicon being 95%. The microstructure of the product is homogeneous, consisting of a basic pearlitic or sorbitic-pearlitic mass having evenly distributed inclusions of graphite in the form of small bent platelets.—S. K.

A Theory to Explain the Occurrence of Graphite Nodules in Cast Iron. P. E. A. van Nieuwland. (*Metalen*, 1953, **8**, Sept. 30, 333–335). [In Dutch]. Assuming that the presence of gas bubbles in the melt is essential for the formation of graphite nodules, its mechanism may be outlined as follows : The surface of the gas bubble absorbs the initial crystallization of the graphite and austenite, the former being acicular and the latter surrounding the bubble. Below eutectic temperatures, carbon diffuses through the austenite film to the gas bubbles. The resulting nodules may be considerably larger than the original bubbles. The gas originally present may either be absorbed by the graphite needles if it does not condense, or even disappear through the austenite.—F. R. H.

High Quality Cast Irons, Especially Those with Compact to Spheroidal Graphite Formation. E. Piwowarsky. (*Giesserei*, 1953, **40**, Sept. 17, 477–482). Previous work on the observation of spherolithic graphite is first discussed and early experiments on its formation described. Spherolithic graphite has been known since 1914, and, since 1923, technological advances have been made by the discovery of cast iron alloys. Since 1891, magnesium and calcium additions to cast iron have been recommended. German and foreign methods for the manufacture of cast iron with compact or spherical graphite formation, without the use of magnesium or cerium, are described.—R. J. W.

The Technology of Producing Cast Iron Treated with Magnesium. K. I. Vashchenko, P. G. Berezin, and A. N. Firstov. (*Liteinoe Proizvodstvo*, 1953, **3**, (1), 18–21). [In Russian]. After a review of factors in nodular cast iron production and utilization which require study, the addition of magnesium and its alloys to cast iron is considered in detail. Russian techniques for carrying out the magnesium additions

are critically reviewed from the aspects of effectiveness, temperature drop, and safety. Data are given on the effects of sulphur, manganese, and silicon, and the hardness and form of graphite in nodular irons containing 0·010–0·052% of magnesium are compared. The harmful effects of phosphorus are capable of mitigation by suitable heat-treatment.—S. K.

Research on the Relation between Cast Iron and Oxygen. II. On the Mechanism of the Formation of White Cast Iron in the Presence of Carbide-Forming Elements. M. Homma and Y. Hashimoto. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1952, **A, 4,** Oct., 447–454). [In English]. Studies were made with manganese, chromium, tungsten, and other elements. The carbide-forming metals behave similarly to oxygen in promoting the formation of white cast iron, as a result of Fe–C–M clusters forming in the melt. There are large differences between the elements. Results are confirmed by experiments in deoxidized melts. (12 references).—K. E. J.

Making Steel Castings from Steel Produced in a Small Converter. M. A. Solntsev, L. M. Chemodanov, and A. A. Kuzin. (*Liteinoe Proizvodstvo*, 1953, (5), 8–11). [In Russian]. Details are given of the production of steel castings for service at temperatures up to 425° C. The steel is made in 2½-ton Bessemer converters with a charge consisting of 50% cast iron, 12% steel scrap 5 to 50 mm. thick, 29·8% of clean foundry steel scrap and 8·2% of ferrosilicon. For cast irons high in sulphur, fluorspar is added to the flux and soda ash to the ladle. Compositions and properties of mould and core-materials are tabulated, and their treatment is described.

Internal Chilling in Steel Casting. V. P. Desnitskiĭ. (*Liteinoe Proizvodstvo*, 1953, **3,** (3), 10–12). [In Russian]. Experiments carried out with various arrangements of chills in test castings are described, and the selection of chill positions in different cases is considered.—S. K.

Mass Production of Cast Steel Parts. S. I. Bernshtein, V. R. Balinskiĭ, and B. I. Shaftan. (*Liteinoe Proizvodstvo*, 1953, **3,** (3), 2–5). [In Russian]. Problems involved in the mass production of corrosion-resisting steel castings for high-pressure work are considered. The steel used had the composition : Mn $\leqslant$1·5%, Cr 17·0–19·0%, Ni 8·0–9·5% and Ti $\leqslant$0·8%. Special attention is devoted to variations in silicon and titanium contents during acid melting and casting. Mechanical properties of cast specimens of different shapes are compared, and the influence of titanium on these properties is illustrated. Results of corrosion and intercrystalline corrosion tests on cast specimens are presented showing the decisive influence of the titanium.—S. K.

Contribution to the Knowledge of Cylindrical Test Pieces for Determining the Properties of Moulding Sand in the Compressed State. W. Götz. (*Giesserei*, 1953, **40,** Sept. 17, 469–477). The characteristic features of the proposed DIN specification 52401 (1953) cylindrical test pieces to determine the properties of moulding sand are described and compared with American test pieces.—R. J. W.

On Testing Sand by Swedish, German, and American Methods. E. O. Lissell and O. Carlsson. (*Giesserei*, 1953, **40,** Sept. 3, 445–454). The Swedish instructions for sand testing are first detailed and then compared with the corresponding German ones. Comparable strength and permeability tests have shown that the test specimens from the different countries give good agreement with the tests results.—R. J. W.

New Production Methods for Grey Iron Castings. (*Met. u. Giessereitechnik*, 1952, **2,** Apr., 121–122). New methods of making grey iron castings have been developed at a foundry making printing machinery. Moulding material consists of a mixture of 8 parts of quartz sand and 2 parts of lignite filter ash, with about 7–8% of a 1 in 30 solution of water-glass, depending on the design and size of casting. A little cement is added for castings above 1 ton. Better surface, 10–15% saving of casting weight, and easier machining are the advantages claimed.—H. R. M.

Influence of the Properties of Foundry Blacking on the Finish of Castings—The NOIRFRAN Specification. P. Nicolas. (*Fonderie*, 1953, Mar., 3351–3356). The author discusses the chemical and physical properties of blackings and their effects on the finished casting. The NOIRFRAN specification for foundry blacking drawn up at the instigation of the Centre Technique de la Fonderie is described.—R. S.

Progress Made in the Development of Synthetic Resin Binders. G. L. Harbach and P. G. Pentz. (*Fonderie*, 1953, Mar., 3331–3343). The author discusses resin-sand mixtures and gives various British formulæ. The economic aspects of these binders are reviewed and some French and British sands are compared.—R. S.

Clays and Bentonites for the Foundry. C. Dias Brosch. (*Bol. Assoc. Brasil. Met.*, 1953, **9,** Jan., 73–108). [In Portuguese]. The various types of clay including bentonites, are discussed in relation to their use in foundry sands and with a view to their standardization. The effects of several variables on the properties of these clays are discussed.—R. S.

Suggested Classification for Wooden Patterns. (*Gjuteriet*, 1953, **43,** Sept., 164–167). [In Swedish]. A Swedish draft classification scheme for wooden patterns is proposed.

Calculation and Construction of Gating Systems for Castings Made by the Lost-Wax Process. S. V. Russiyan and N. N. Golovanov. (*Liteinoe Proizvodstvo*, 1953, (5), 5–8). [In Russian]. Examples are given showing the importance of correct design of gating systems for casting by the lost-wax process, and an appropriate method of calculation is suggested. Equations for finding mould filling time and the total feeder cross-sectional area are presented together with values of the coefficients for steel and cast iron.—S. K.

Accurate Disposition of Vents in Pressure Casting. E. G. Kopanevich. (*Liteinoe Proizvodstvo*, 1953, **3,** (1), 7–10). [In Russian]. Factors leading to the misplacing of holes in pressure die castings are considered. Equations allowing for these factors under a variety of conditions are presented.

Sandslinger Applications. M. F. Putz. (*Amer. Foundryman*, 1953, **24,** Sept., 39–44). The use of a sandslinger in mould ramming is discussed with reference to both jobbing and production foundries. The sandslinger can be manually or hydraulically operated and may be used in conjunction with a roller conveyor or, for greater flexibility, with a turntable. For large moulds an electrically driven mobile slinger can be used to cover a wide strip on either side of the track ; maximum capacity is obtained with a hydraulically operated mobile slinger. With complete standardization, automatic sling ramming is possible and over 200 moulds per hour can be produced.—B. C. W.

Use of Self-Developing Camera to Set Core-Making Standards. F. C. Adams and R. S. Foerster. (*Amer. Foundryman*, 1953, **24,** Sept., 46–47). A self-developing camera that produces a positive print within 1 min. was used to record the details of foundry cores. The dimensions were marked with crayon on the glazed print which, together with a list of materials, provides a complete record of the core.—B. C. W.

Rationalizing the Machine Moulding of Small Castings. E. O. Lissell. (*Gjuteriet*, 1953, **43,** Sept., 159–163). [In Swedish]. Proposals are made for rationalizing foundry operations. A well-controlled synthetic sand should be adopted which should be thoroughly cleaned after use. Other suggestions include : Improved quality of patterns ; use of modern rapid moulding machines of the jolt-squeeze type ; and standard moulding boxes. Details are given of a simple mechanization scheme using small wheeled pallets run on angle irons and returned on roller conveyors.—G. G. K.

Effect of Height of Jolting and Number of Jolts on the Consolidation of Sand Moulds. N. N. Anashenko. (*Liteinoe Proizvodstvo*, 1953, (5), 16). [In Russian]. The results of experiments in which 400 × 600 × 400 mm. sand-filled moulds were subjected to various numbers of jolts from different heights are presented. These numbers and heights are tabulated together with the resulting surface hardnesses and densities.—S. K.

Equipment for Automatically Knocking out Moulding Boxes. N. I. Khandin. (*Liteinoe Proizvodstvo*, 1953, (1), 14–15). [In Russian]. Methods developed at the Stalin motor-car factory for automatically knocking out moulding boxes are described.—S. K.

Moulds for Casting Iron Worm Gears and Screw Conveyors in Practice. (*Giesserei*, 1953, **40,** Sept. 17, 486–488). Six diagrams clearly illustrate the types of gear wheels and screw conveyors in use and methods of casting them. Moulds for small and medium sized transmission gears and moulds for larger driving gears are discussed.—R. J. W.

Making the Mould, without Pattern and Core Box for a Bend with Five Cast Flanges. L. Queck. (*Giesserei*, 1953, **40,** Oct. 15, 572–575).

Casting Cylinders and Cylinder Blocks. A. I. Budyaev, N. L. Manuilov, and I. N. Iukalov. (*Liteinoe Proizvodstvo*, 1953, **3,** (1), 2–4). [In Russian]. Details are given of some mould pouring arrangements for the production of high quality cylinders and cylinder blocks at a Russian factory.—S. K.

Experiences in the Production of Thin-Walled Grey Cast-Iron Cylinders. A. Winter. (*Giesserei*, 1953, **40,** Sept. 3, 460–462). In the successful manufacture of cast thin-walled cylinders, careful attention must be paid to detail. Descriptions are given of the sand treatment necessary, the making of the cores, gating technique, sorting to obtain the correct material, the casting operation, and finally, the handling after casting. Five diagrams demonstrate these points.—R. J. W.

The Significance of the Shell Moulding Process for the Dutch Foundry Industry. H. van Suchtelen. (*Metalen*, 1953, **8,** Aug. 15, 291–296 ; Aug. 31, 303–306). [In Dutch]. The metallurgical aspects, advantages, disadvantages, and the patent position of the shell moulding process are discussed.

Accuracy and Surface Quality of Castings Made by the Lost-Wax Process. A. S. Smirnov and M. M. Pevzner. (*Liteinoe Proizvodstvo*, 1953, (5), 3–5). [In Russian]. This is a general discussion of the dimensional and shape accuracy of castings produced by the lost-wax process, and of the effect of mould-preparation and other factors on their surface quality.—S. K.

Centrifugal Casting of Piston Rings. P. I. Anpilogov. (*Liteinoe Proizvodstvo*, 1953, **3,** (1), 4–6). [In Russian]. The qualities required of piston rings for high-speed Diesel engines are considered, and the experimental replacement of the cored mould by centrifugal casting for the production of the ring pots (cylinders from which the rings are cut) is described. For producing the iron used in the experiments, the operation of the cupola and the casting process were adjusted so that a hot iron with a high combined-carbon content was obtained. Good rings were made by centrifugal casting from an iron with the composition : Total C 3·16–3·79%, combined C 0·63–0·88%, Mn 0·79–1·27%, Si 1·33–1·93%, S 0·02–0·08%, P 0·32–0·58%, Cr 0·14–0·38%.—S. K.

Centrifugal Castings of Piston Rings and Bearings. E. M. Baturin. (*Liteinoe Proizvodstvo*, 1953, **3,** (3), 5–9). [In Russian]. The technique of centrifugal casting of piston rings and cylinder liners adopted at a Russian factory is outlined, and the factors influencing the properties of the products are considered. The wear resistance is related to the state of the graphite. Micrographs show the microstructures produced under various conditions. Chemical compositions and hardnesses of piston rings from various Russian and foreign works are compared, the composition recommended for centrifugal casting is C 3–3·4%, Si 1·5–1·7%, Mn 0·8–1·2%, P 0·4–0·6%, S 0·1%, Cr 0·15–0·3%, and Ni 0·2–0·4%.

A Special Report on European Foundry Progress—Britain. E. Longden. (*Foundry*, 1953, **81,** Sept., 102–105). The author reviews developments in British foundry practice during the last ten years. While production of grey iron and malleable iron has increased by 15% between 1938 and 1952, that of cast steel increased by 95% in the same period.

A Special Report—France. (*Foundry*, 1953, **81,** Sept., 106–107). Foundries are well spread throughout France, and for those not equipped with a laboratory, ten co-operative laboratories are dispersed over the country ; these are functioning at full capacity. Quality specifications are being developed.—R. A. R.

A Special Report—Belgium. J. F. Goffart. (*Foundry*, 1953, **81,** Sept., 108–109). There are no less than 466 foundries in Belgium. Production costs are kept down by : (*a*) Professional organization, thorough scientific research, economic study and technical research ; and (*b*) technical improvements brought into actual works practice. With American collaboration, roll founders have solved problems arising from the new specifications for rolls used in four-high plate mills.

A Special Report—Italy. M. Olivo. (*Foundry*, 1953, **81,** Sept., 110–111). About 500,000 tons of castings were produced in Italy in 1952, the man-hour production having risen from 10·7 lb. in 1947 to 14·3 lb. in 1952. Methane (natural gas) is abundantly available in Italy and, as soon as pipelines are laid, foundries will eagerly use it for mould and core baking, and drying ladles.—R. A. R.

A Special Report—Netherlands. F. W. E. Spies. (*Foundry*, 1953, **81,** Sept., 112–113). Production by the iron foundries has risen from 102,000 tons in 1938 to 196,000 tons in 1951, and about 8,000 tons of steel castings were made in the latter year.—R. A. R.

A Special Report—Germany. E. Hugo. (*Foundry*, 1953, **81,** Sept., 114–115). This report on the foundry industry in Germany describes the technical training methods, and mentions some changes in practice. In 1948 Germany had only two or three hot-blast cupolas in operation, whilst in 1953 a total of 80 are in operation and under construction.—R. A. R.

Production Planning in the Foundry. T. N. Sokolov. (*Liteinoe Proizvodstvo*, 1953, **3,** (3), 12–14). [In Russian]. Planning aids for mass production in the foundry are outlined, and the organization of such work is discussed.—S. K.

Contribution to Shrinkage Cavity Formation in Grey Cast Iron. L. Hütter. (*Giesserei*, 1953, **40,** Sept. 3, 455–457). The connection between the volume change on solidification and pipe are first discussed. A series of experiments were carried out on a number of thin-walled castings, with and without cavities. Both chemical and microscopical techniques were employed. These showed simply that the formation of cavities depended on the amount of eutectic precipitated graphite present. When above 2·2% graphite was present, cavities were not found, whereas below this figure they were. The influence of silicon on this graphite separation is considered.—R. J. W.

Gas in Pig Iron and Cast Iron. J. E. de Graaf. (*Metalen*, 1953, **8,** Sept. 15, 319–324). [In Dutch]. A comparison is made of the solubilities of hydrogen, nitrogen, and oxygen in pure iron and pig iron, supersaturation being frequently found without the corresponding blowholes; this can be attributed to resistance to bubble formation. The gas content can be reduced by efficient cupola operation. Blowholes are sometimes caused by the iron coming into contact with moisture in refractories. The gas content is not influenced by casting the iron on a sand bed or in iron moulds.—F. R. H.

Hydraulic Cleaning of Castings. N. A. Anurov. (*Liteinoe Proizvodstvo*, 1953, (5), 17–19). [In Russian]. The theory of the disintegration of a material by sand-blasting and by a high velocity jet of liquid is considered, with special reference to the use of water jets for cleaning castings. Jets of water at a velocity of about 140 m./sec. are recommended. The effect of sand in a gas stream on metal surfaces was also investigated.—S. K.

"Roto-Finish"—The Level, Mechanical-Chemical Process for the Removal of Casting Fins, and Grinding and Polishing of Mass-Produced Articles. I. H. Nann and H. A. O. Fitzler. (*Metalloberfläche*, 1953, **7,** Mar., B41–B47). After a general survey of methods of dressing, grinding and polishing mass-produced castings and forgings, the principle, mode of operation and range of applicability of the Roto-Finish process are described. Working details are given, with examples of articles treated by the process.—L. D. H.

Application of External Dust Control to a Standard 24-in. Pedestal Grinder. Part I—Dust Control System. W. H. White. **Part II—Dust Observations and Determinations.** W. B. Lawrie. (Inst. Brit. Foundrymen : *Foundry Trade J.*, 1953, **95,** Oct. 15, 481–487).

HEATING FURNACES AND SOAKING PITS

Current Steelworks Problems: Quality and Cost Loom Larger as Steel Markets Change. (*Iron Coal Trades Rev.*, 1953, **167,** Oct. 23, 939–942). The importance of maintaining the highest quality in the steel industry is emphasized in view of the rapid change from a sellers to a buyer's market. Some current steelworks quality problems are discussed, particular attention being given to methods of reducing or preventing air infiltration in heating furnaces.—G. F.

Model Experiments to Elucidate Flow Processes in Soaking Pits. M. Hansen, H. Scholz, and O. J. Stebel. (*Arch. Eisenhüttenwesen*, 1953, **24,** Sept.-Oct., 375–381). The use of models to investigate flow patterns in top-heated soaking pits is discussed. Tests on models of Stein-Roubaix and AMCO soaking pits are described. In the former, with one burner only, the gas flows, in general, across the top of the pit, down the wall opposite the burner, along the floor, and out of the gas exit. A portion is carried up along the burner wall by the suction created by the flame so that there is a vortex in the pit with a horizontal axis at right angles to the direction of the gas inlet. In the AMCO design, with burners on opposite walls, there is a vortex, with a vertical axis, moving down towards the bottom of the pit. This gives good washing of all ingots, even of those not subject to radiation from the walls. Slight rotation of the individual ingots from a rectangular position improves the flow of gas over them considerably. All experimental results have been confirmed in practice.—J. P.

The Reconstruction of a Soaking Pit Building. H. C. Husband and K. H. Best. (*Structural Eng.*, 1953, **31,** Nov.,

301–315). The authors describe the problems encountered and their solutions during the design and construction of a welded steel frame building in a highly congested area at the Stocksbridge steelworks of Samuel Fox and Co., Ltd.—R. A. R.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Heat-Treatment of Steel. J. C. C. Stegwee. (*Metalen*, 1953, **8,** Nov. 15, 382–388). [In Dutch]. The author traces the development of tool steel and points out that the heating time is just as important as the hardening temperature. Micrographs showing the effects of these two factors on the grain size of tool steel are presented. Curves are also given indicating the effect of time and temperature on the physical characteristics of these steels.—F. R. H.

Investigation into the Heat-Treatment of Ingot Mould Materials. H. Gau and W. Küntscher. (*Met. u. Giesserentechnik*, 1952, **2,** Apr., 98–100). Tests on an ingot mould iron (0·48% combined and 3·04% graphitic carbon, 2·93% Si) showed that an annealing treatment at a suitable temperature could produce a ferritic structure which had increased bending strength and reduced sensitivity to cracking on repeated quenching. Such a treatment applied to moulds led to an average increase in mould life of 30%, and in the case of a thick-walled mould of unfavourable shape, an increase of 200%.—H. R. M.

Heat Treat Line Tells Handling Story. (*Steel*, 1953, **133,** Oct. 5, 134–135). The operations in a mechanical production line for heat treating up to 1,400 lb. of screws per hour are described. The fully automatic sequence is : Weigh, wash, harden, quench, wash, temper, and rustproof.—D. L. C. P.

Town Gas As an Industrial Fuel. A. de Jerphanion. (*Usine Nouvelle*, 1953, **9,** Spring Issue, 59–64). The properties of town gas which have led to the rapid increase in its use as an industrial fuel are described. Applications mentioned include gaseous cementation, the production of controlled atmospheres for bright annealing, and infra-red and high-temperature radiant heating.—A. G.

A Controlled Atmosphere for Steel with Adjustable Carbon Potential. J. W. Hollerman, W. A. Schultze, and M. A. de Jongh. (*Metalen*, 1953, **8,** July 15, 263–266 ; July 31, 279–282). [In Dutch]. A survey is made of the fundamental features of controlled atmospheres for the heat-treatment of steel with emphasis on the need for rapid adjustment of the carbon potential of the protecting gas. A simple installation of this kind is described in which the atmosphere is adaptable to any carbon content in steel ranging from 0·2 to 1%.—F. R. H.

Heat-Treatment of Large Parts. E. Páral. (*Hutník* (Prague), 1953, **3,** (9), 199–202). [In Czech.]. An account is given of the heat-treatments necessary in the manufacture of large crank-shafts and rolling-mill rolls.—P. F.

Needle Making in Britain. (*Wire Prod.*, 1953, **2,** Aug., 9–11). A short account of needle manufacture in Great Britain is given with special reference to heat-treatment for which 6-kW. vibrator tube furnaces with an output of 15 lb./hr. are used.—R. A. R.

Spectrographic Analysis of Metal Surfaces, in Particular the Determination of Carburization and Decarburization. W. Liedtke. (*Trans. Instruments and Measurements Conf.*, Stockholm, 1952, 44–46). [In German]. When analysing surface decarburization or recarburization spectrographically, the depth of the crater must be less than 5μ. A traversing spark method, in which the average penetration is 2μ is described. Details of the apparatus and excitation conditions are given. The method is also applied to the determination of the carbon content across the section of the specimen, by grinding off successive layers.—L. D. H.

Economies Effected by Surface Flame Hardening. H. W. Grönegress. (*Rev. Mét.*, 1953, **50,** Sept., 635–641). Advantages of the method include the replacement of case-hardening alloy steels by flame-hardened ordinary steels, and the possibilities of increasing the wear resistance and fatigue limit of parts by flame-hardening. The method also enables bronze bearings to be replaced by sintered iron, plastic, or lead-bronze liners. Examples of flame-hardened pads in mining equipment and the iron and steel industry are given.—A. G.

Induction Heating in Automobile Engineering: Economies Possible in Production Lines. R. B. Osborn, jun. (Amer. Inst. Elec. Eng. Conf.: *Iron Coal Trades Rev.*, 1953, **167,** Oct. 30, 1019–1021). The possible economies and other benefits which may be obtained by applying electric induction heating techniques in engineering production lines are discussed, and possible applications, including heat-treatment, are outlined.

Carbonitriding Atmospheres. B. Přenosil. (*Strojírenství*, 1953, **3,** (9), 659–666). [In Czech]. A comparison between carbonitriding and gas carburizing shows several advantages of the former method. Thus a higher hardenability of the surface facilitates oil-quenching which, together with the lower hardening temperature, decreases the deformation. Further, coarsening of the austenite grain is prevented. Carbon diffusion in the steel is accelerated by the simultaneous diffusion of nitrogen. Retained austenite content can be minimized by a suitable nitriding atmosphere, and by chilling after tempering. Atmospheres consist usually of an ammonia-hydrocarbon mixture, perhaps with a carrier gas. Diagrams are given for the graphic determination of the carburizing potentials of various carbonitriding atmospheres, and of the equilibria between components of water-gas, and of water-gas and methane. The ability of any given atmosphere to saturate the metal surface with nitrogen cannot be determined by thermodynamics. The most suitable ammonia content has to be determined experimentally.—P. F.

Progress in the Field of Gas Carburization. C. A. Landiermann. (*Metalloberfläche*, 1953, **7,** Sept., A137–A139). A description is given of the principles and method of operations of the Carbonitriding case-hardening process. The structure obtained at various temperatures, and the influence of temperature on the carbon and nitrogen distribution are discussed, and details of the heat-treatment equipment and operation are given.—L. D. H.

Quenching of Basic-Bessemer Steel from the Rolling Temperature in Full-Scale Operation. F. Kösters. (*Stahl u. Eisen*, 1953, **73,** Oct. 8, 1342–1349 : *Iron Steel Inst. Translation Series No.* 481, 1954). The design and operation of a plant for hardening round steel bars and steel sections from rolling temperature is described. Steels can be hardened in this way so as to possess satisfactory tensile and impact properties. Tensile tests on specimens of water-quenched steel after several years' storage showed that the yield point was unchanged and the tensile strength had decreased slightly. Elongation had, however, increased. Tests on welded specimens indicated that water-quenching after welding eliminates any effect of heating on tensile properties.—J.P.

Heat Treatment of Wire. (*Wire Prod.*, 1953, **2,** Sept., 13). A plant for the continuous annealing of wire by induction heating, with means for providing a non-oxidizing atmosphere, has been outlined in British Patent No. 695, 220 of the Metropolitan-Vickers Electrical Co. Ltd. The process is briefly described.—J. G. W.

On the Theory of Quenching of Steels. K. Honda. (*Proc. Japan Acad.*, 1946, **22,** Apr., 78–83). [In English]. Quenching of steel can be satisfactorily explained in terms of lattice and diffusion changes. The extent of the A_1 transformation depends on the transformation force, internal resistance to lattice change, and velocity of cooling.—K. E. J.

The Various Industrial Aspects of the Phenomena of Steel Tempering. A. Portevin. (*Metalen*, 1953, **8,** June 30, 247–250 ; July 15, 267–272 ; Aug. 15, 298–300 ; Aug. 31, 307–310). [In French]. This is an analytical review considering the tempering of steel from both the theoretical and practical standpoints. The whole theory of tempering is outlined with the aid of five examples. For simplification, the influence of the pretreatment of the steel, tempering time, and inclusions is ignored but the following are dealt with : Difference in composition in the same sample ; non-uniform annealing or cooling (even after welding or case-hardening) ; and the less desirable effects such as deformation and internal stresses ; and the need for a fine grain. The TTT diagram, now widely used, deals only with limited aspects of the general problem.

FORGING, STAMPING, DRAWING, AND PRESSING

Heavy Forging Practice. F. A. Hamilton. *See* p. 311.

Modern Trends in the Manufacture and Use of Cold Upsetting Tools. J. Billigmann. (*Draht., English Ed.*, 1953, Sept., 19–23). This is a review of modern developments in the tooling of cold heading machines, notably the use of cold drawn stock, hot pressing, and the manufacture of tools by coining and embossing.

Automatic Feed Pressworking with Particular Reference to the Working of Thin Gauge Soft Metals. C. H. Crawford. (*J.*

Junior Inst. Engineers, 1953, **64**, Oct., 1–36). A detailed account is given of the tools and processes used in automatic feed pressing operations.—R. A. R.

How Patenting Speed Influences the Quality of Drawn Wires. M. Sýkora. (*Hutník* (Prague), 1953, **3**, (9), 202–204). [In Czech]. Results of 27 experiments on patenting and drawing 0·66%-C steel wires for wire ropes are described. Wires 5 mm. in dia. were drawn down to 3·5 mm. at speeds of 1, 2·3, and 5 m./min. At each speed wires which had been cooled to 800, 875 and 960° C. respectively were used, and with each of these temperatures lead-bath patenting temperatures of 450, 500 and 560° C. were employed. Cooling temperatures were not found to influence the drawability noticeably ; it was highest in wire, patented at 560° C. at a speed of 5 m./min. which had cooled to 800° C., being 10%. Bend tests showed that patenting temperatures influenced the bend strength very little, and that cooling temperatures were unimportant from that point of view, though best results were obtained by cooling from a temperature of 960° C. to a bath temperature of 450° C. Strength in torsion fell with decreasing cooling temperature, irrespective, of bath temperature in going from the medium to the high patenting velocity.

ROLLING-MILL PRACTICE

Modern Rolling Mills. B. Ondrák. (*Hutník* (Prague), 1953, **3**, (7–8), 146–151). [In Czech]. The layout and mode of operation of modern rolling mills of continuous and other types are surveyed. Design and performance of soaking pits, blooming mills and strip mills are discussed.—P. F.

The Use of Rotary Controllers in Rolling Mills. A. Kuba. (*Hutník* (Prague), 1953, **3**, (7–8), 151–156). [In Czech]. Automatic control in rolling mills with apparatus of the Amplidyne, Rototrol, Regulex, and VSA-types is discussed.

Maintenance Experience on 600-Volt Rectifiers. R. T. Lucas and H. K. Fish. (*Iron Steel Eng.*, 1953, **30**, Sept., 184–187). A brief description is given of the maintenance experience gained at Weirton Steel Co. with their two new 3500-kW. rectifiers supplying 600 V. An indication is given of maintenance procedure and the spares carried.—M. D. J. B.

Cast-Iron Rolls. H. Poetter. (*Met. u. Giessereitechnik*, 1952, **2**, Apr., 127–136). The author gives information to the roller to assist in choosing the right roll material, The structure and properties of the different types of iron used for rolls, hardness and methods of measuring it, and production methods are described, and suitable types and hardnesses of iron for different types of rolls are listed. Roll breakage and its causes are also discussed.—H. R. M.

A Heavy-Duty High-Speed Roll Neck Bearing. P. L. Haager. (*Iron Steel Eng.*, 1953, **30**, Sept., 158–163). The new bearing described consists of four rows of rollers with the outer rows arranged to permit maximum neck diameters and improved load distribution over all the rollers in the bearing. A new hydraulic jack and a new air gauge make it easier to fit bearings to roll necks.—M. D. J. B.

Steel Rolling Mill Practice in Australia. M. R. Pitt. *See* p. 311.

Rolls and Rolling.—Rails. E. E. Brayshaw. (*Blast Furn. Steel Plant*, 1953, **41**, Apr., 399–407 ; Sept., 1040–1047 ; Oct., 1176–1186). Continuation of a series of articles (*see J. Iron Steel Inst.*, 1953, **174**, July, 280). The use of the diagonal system of rolling for producing rails from billets and the rerolling of old rails to give new rails of smaller size or to give a billet, are described. Pass design for the rolling of groove, guard, and girder rails are described in detail. The design of suitable presses is also discussed in detail.—B. G. B.

Economics Effected in Roller Guide Applications. H. Gassner. (*Iron Steel Eng.*, 1953, **30**, Sept., 192–194). A brief description is given of the Meehanite type, G. M. roller twist guides at the Aliquippa bar mill of the Jones and Laughlin Steel Corp. These rollers used on the 21 and 18 in. mills, provided the record of 22,000 tons before reversal.

Pittsburgh Steel Begins Hot Strip Mill Operation. (*Blast Furn. Steel Plant*, 1953, **41**, Sept., 1053–1056). A short account of this new 66 in. semi-continuous hot strip mill is given. Monthly output is to be limited at first to 50,000 tons. The sheet sizes run from 20 to 60 in. wide and from 0·065 to 0·188 in. thick. Slabs, brought from a separate works, are heated in gas-fired furnaces. The present finishing mill consists of four 4-high finishing stands in tandem.—B. G. B.

The Continuous Rolling of Stainless Steel at the New Shepcote Lane Works, Sheffield. (*Sheet Metal Ind.*, 1953, **30**, Sept., 709–722, 731–746, 755–762). **Firth-Vickers Stainless Steels Ltd.** (*Anvil*, 1953, **3**, Summer, 4–9 ; *Engineering*, 1953, **176**, Sept. 11, 332–333 ; Sept. 18, 362–365). The raw material at this completely new works consists of slabs 20 in. wide × 4½ in. thick in lengths up to 42 in. These are heated in a pusher furnace 53 ft. long × 12 ft. wide. The two-high roughing mill with rolls 35 in. dia. × 72 in. long reduces the slabs to 1¼-in. plates. The cold-finishing mill is a four-high reversing stand with work rolls 17 in. in dia. and backing rolls 49 in. in dia., all with 50-in. faces. This stand is driven by a 1500-h.p. motor. There is also a Sendzimir cluster-type cold mill with work rolls 2⅛ in. in dia. backed by four 4-in. intermediate rolls, with six more rolls 6⅛ in. in dia. outside of these. The mill is designed to produce 20,000 tons/year of stainless steel sheets up to 33 ft. wide.—R. A. R.

Application of Statistics to the Steel Industry: An Investigation into the Occurrence of Defectives in a Rolled Steel Product. J. E. Andrew. (*Iron Coal Trades Rev.*, 1953, **167**, Oct. 30, 1003–1009). As an example of the usefulness of statistics in the steel industry, the author describes an investigation into the occurrence of rejects in a rolled steel product. The collection of data and the application to them of statistical techniques, allowed recommendations to be made which resulted in a considerable improvement in the incidence of rejects.—G. F.

New Seamless Mill Rolls into Action. (*Steel*, 1953, **133**, Oct. 12, 97–99). The development of the Colarodo Fuel and Iron Co. is first described, and their new seamless tube mill is then dealt with. Full output will be up to 150,000 U.S. tons/year of pipe up to 9 in. in dia. Billets are heated in a rotary hearth furnace. Cylinders formed on one or two piercing mills are rolled out over a mandrel. After burnishing, pipes are turned out to finished size on a 7-stand sizing mill or a 14-stand reducing mill.—D. L. C. P.

Making Mill Effluent Pay Off. R. W. Simpson and W. Garlow. (*Steel*, 1953, **133**, Oct. 19, 90–92). Sedimentation basins are being used to advantage in the recovery of mill scale and cooling water. Three examples are cited. One plant handles 13,000 U.S. gal./min.—D. L. C. P.

Stamping of Rolled Products at the Hot Saw, Hot Shear and Straightening Machines. H. Zimmer. (*Stahl u. Eisen*, 1953, **73**, Aug. 27, 1174–1176). Methods are described for machine and hand stamping of identification marks on various shapes of hot cut and straightened products.—J. P.

MACHINERY FOR IRON AND STEEL PLANT

A Maintenance Material Programme. J. E. Anderson and J. B. Whitlock. (*Iron Steel Eng.*, 1953, **30**, Sept., 75–81). The author classifies material failures into four groups : Improper design of section, misapplication of material, inferior installation, and abuse of equipment. Examples of failures in steel plant equipment are cited with notes on methods of prevention.—M. D. J. B.

Maintenance of Industrial Electronic Equipment. W. Few. (*Iron Steel Eng.*, 1953, **30**, Sept., 179–182). The author puts forward suggestions which will be found helpful for the preventive maintenance and servicing of industrial electronic equipment.—M. D. J. B.

Considerations in the Design of Plain Bearings. A. E. Cichelli. (*Iron Steel Eng.*, 1953, **30**, Sept., 164–174). This paper follows up the Plain Bearing Recommended Practice of the Assoc. Iron Steel Engineers and defines the engineering approach. The author reviews the background theory and principles and then applies them to a typical steel mill bearing problem.—M. D. J. B.

Causes and Prevention of Premature Gear Failures. R. Johnson, jun. and S. D. Craine. (*Iron Steel Eng.*, 1953, **30**, Sept., 118–128). The authors describe the major causes of gear failures and correlate gear design and operation with lubrication. The effects of tooth surface irregularity, abrasives in the oil, mechanical damage to teeth, metal failure, failure of the lubricant, misalignment, and thrust are examined.

Temperature and Movement of Plain Cylindrical Bearings at High Revolutions. H. Stephan. (*V.D.I.-Forschungsheft* 439, 1953).

Modern Industrial Boiler Plant. W. P. C. Ungoed. (*J. Iron Steel Inst.*, 1954, **176**, Mar., 283–291). [This issue].

LUBRICANTS AND LUBRICATION

Status of Lubricant Standardization for Lubrication in Iron and Steel Works. F. Eisenstecken. (*Stahl u. Eisen*, 1953, **73**, Sept. 24, 1289–1293). The importance of lubrication in steelworks, the existing German standards for lubricants, and the requirements for new standards are briefly discussed.

Techniques and Applications of Machine Lubrication. J. Prevost. (*Usine Nouvelle*, 1953, Feb. 5, 27–30 ; Mar. 26, 27–31 ; May 7, 53–59 ; May 28, 51–56 ; June 11, 25–31). The choice of hydraulic systems and fluids, is discussed and oils suitable for brakes, shock absorbers, and couplings are recommended. All the variables involved in bearings such as size of part, state of surface, viscosity of oil, and relative speed of surfaces may be related in a hydrodynamical theory of oil films. The use of diagrams showing the relations between the main variables is considered.—A. G.

WELDING AND FLAME-CUTTING

" Bulbider " E.S.A.B.'s New Tool to Assist the Welding Industry. (*Svetsaren*, 1953, **18**, (2), 21–23). [In Swedish]. To avoid the use of heavy weights to press down and align plate edges in preparation for welding, Elektriska Svetsningsaktiebolaget (E.S.A.B.) has brought out an electromagnet weighing 30 kg. exerting a pull of 600 kg. which does the required work and is very easy to manipulate.—R. A. R.

The Development of Lime Basic Coatings for Plain Carbon Steel Welding Electrodes. C. De Rop and H. Schmidt-Bach. (*Stahl u. Eisen*, 1953. **73**, Sept. 10, 1212–1215). Lime-fluorspar-coated plain carbon steel electrodes may be used to produce good welds in unalloyed and manganese structural steels, provided that precautions are taken to keep the coating dry and to use the electrodes in the correct way. Advice is given on this aspect.—J. P.

Developments in Submerged Melt Welding for Steel Plant Maintenance. D. E. Knight. (*Iron Steel Eng.*, 1953, **30**, Sept., 98–104). The author describes a means of resurfacing worn parts in such a manner that the successive weld beads will form a smooth bright surface, free from defects, which will machine easily. Numerous examples are given of re-surfaced rolls, shafts, worn bores, rams, and shear blades.

Plant Welding Applications. H. J. Ralston. (*Iron Steel Eng.*, 1953, **30**, Sept., 105–112). The author discusses the advantages of welding as a means of rehabilitating worn parts and describes the new rapid techniques for depositing weld metal on cylindrical parts.—M. D. J. B.

Possibilities in the Production and Repair of Tools by Hard Facing. O. Zabara. (*Dyna*, 1953, **28**, June, 174–180). [In Spanish]. Various classes of welding electrode are described. Precautions to be taken in applying the hard metal by oxy-acetylene and electric arc welding processes are mentioned.

The Fully Automatic Production of Resistance Welded Wire Mesh from Cold Formed Steel Wires. H. Wedl. (*Draht, English Ed.*, 1953, Sept., 37–43). Metallurgical requirements of wire for the manufacture of welded grids are discussed. The stress-strain curve of the wire is indicated. Details of a welding machine are given.—J. G. W.

The Weldability of Heat-Resisting Steels of the Molybdenum-Vanadium-Alloyed Type. S. E. Erikson. (*Svetsaren*, 1953, **18**, (2), 19–20). [In Swedish]. An investigation is reported which showed that the welding of the above type of steel is not more difficult than the welding of chromium-molybdenum steels.—R. A. R.

Radiographic Examination of Welds: A Complete Assessment of the Defects in Terms of Tensile and Fatigue Strength. O. Masi and A. Erra. (*Metal. Ital.*, 1953, **45**, Aug., 273–283). Previous investigations at The Breda Institute made it possible to calculate the static failure point on welded test pieces after photometric measurements had been taken. This was done by establishing a correlation between fatigue limit and radiographic evaluation. This evaluation was defined by grouping the specimens into classes of various radiographic qualities, calculating the ultimate strength for each class, and then determining the fatigue limit. With the knowledge of these two values the authors establish a ' calculated-static-load/fatigue-limit diagram ' from which they deduce that the influence of weld defects is relatively more serious for small or few defects, diminishes as the defects increase until such time as the cross section is reduced by about 5%, when a linear relationship can be established between the deterioration at static and at alternating loads. The method provides a means of establishing a criterion for radiographic examination.—M. D. J. B.

The Influence of Electrode Coatings on the Formation of Flakes in Unalloyed Steel Welds and Their Origin. F. Erdmann-Jesnitzer and H. Kowalkowski. (*Arch. Eisenhüttenwesen*, 1953, **24**, July-Aug., 361–368). Systematic tests on the influence of different welding electrode coatings on the formation of flakes have shown that wood flour and kaolin are hydrogen formers and that adding ferromanganese promotes flake formation. Modified coating compositions are given which allow the production of flake-free welds. Tensile and bend tests on specimens annealed, unannealed and cathodically charged with hydrogen, and X-ray examination during tensile testing of welded bars, have shown that flakes occur under tensile stress in the region of the yield point. The occurrence of flakes is attributed to diffusion of atomic hydrogen to pores and the formation there of molecular hydrogen at high pressure.—J. P.

The Fatigue Strength of Untreated Welded Joints in Steel Qmc 37 Made with Basic-Coated Electrodes. (*Lastechn.*, 1953, **19**, Oct., 200–209). [In Dutch]. The tensile fatigue limit when low-hydrogen electrodes are used is compared with the value obtained with the iron oxide coated electrodes ; the values are 21,000 and 24,000 lb./sq. in. respectively. This difference is related to the rough weld surface. It is suggested that electrodes providing a smoother and more notch-free surface be used instead of low hydrogen electrodes for surface layers.—F. R. H.

New Apparatus for Cutting Cast Iron. O. Sh. Spektor. (*Liteinoe Proizvodstvo*, 1953, **3**, (1), 15). [In Russian]. The application of the oxygen-flux method to cast iron is described. The type of apparatus used is the same as that for high-chromium steels and non-ferrous metals, while the cutting process resembles that for low-carbon steel.—S. K.

On the Research of Welding and Welding-Rod for Cast Iron. Report 1. The Investigation of Commercial Welding-Rod for Cast Iron. K. Yokota and S. Eto. (*Wasada Univ. Rep. Castings Res. Lab.*, 1953, June, 60–62). [In English]. Mild steel, copper, and brass core rods are unsuitable for electric-arc welding of cast-iron plate, since an extremely hard zone results. Good results were obtained by oxy-acetylene welding, using nickel, monel, Ni–Cu–Zn, and cast-iron filler rods.

Oxygen Cut-Offs in the Hot Mill. R. L. Deily. (*Steel*, 1953, **133**, Oct. 5, 98–100). It is reported that oxygen cutting machines are gaining favour for cutting hot blooms and slabs in the mill line. Robust construction gives almost 100% availability. An example is cited of an installation on a hot slab-line, where slabs up to 6 in. thick and 74 in. wide are cut by a pair of torches working towards each other. There are two pairs of torches, one of which can move down the line while cutting, and one fixed.—D. L. C. P.

MACHINING AND MACHINABILITY

Surface Finish and Surface Function—Requirements and Possibilities. H. Hallendorff. (*Tekn. Tidskr.*, 1953, **83**, Sept. 29, 709–715). [In Swedish]. Swedish standards for surface finish are based on maximum permissible profile depth in μ, as opposed to the English average height and the American root-mean-square height. Differences in the three methods are briefly discussed.—G. G. K.

Measurement of Surface Finish. B. Linbeck and A. Mannheimer. (*Tekn. Tidskr.*, 1953, **83**, Sept. 29, 716–721). [In Swedish]. After demonstrating the impossibility of directly converting the Swedish value H (profile depth in μ) into the English American units, the author describes the main functions of the two main classes of instruments—optical and stylus—used for measuring the surface roughness of metals.

Experience with Swedish Standards for Surface Finish. A. Eriksson. (*Tekn. Tidskr.*, 1953, **83**, Sept. 29, 721–724). [In Swedish]. The two methods of denoting the requisite surface finish, laid down in the Swedish 1947 Standards 671 and 672 are described. Some problems encountered by a Swedish aircraft engine factory in applying the new values are discussed.—G. G. K.

Surface Finish and Modern Production Engineering. D. M. Carroll. (*Australian Machinery*, 1953, **6**, Mar., 10–13, 15–25, 27–50). Types of surface finish and present American and British specifications for its evaluation are first discussed. A resumé of the usual methods of evaluating and measuring surface quality (visual, optical, tracing instrument) is given.

The use of calibrated specimens for normal production requirements is described and advocated.—P. M. C.

Some Aspects of the Relation of the Microstructure of Surface Layers Before and After Processing to the Finish of Metal Surfaces. E. Pohl. (*Australian Machinery*, 1953, **6**, Apr., 7–9, 11–17). The author deals with the effect of microstructure on machinability. Best machining characteristics are obtained from a material with a combination of low strength, low ductility, and low abrasive hardness. Carbon steels are considered first ; the effect of composition and heat-treatment on the microstructure is discussed, and the relative merits of lamellar and spherodized cementite and inclusions are outlined with reference to machinability. Stainless steels are also considered.—P. M. C.

Modern Trends in the Selection of Steels. G. M. Flather. (*J. Inst. Prod. Eng.*, 1952, **31**, Dec., 600–611). Methods used in the selection of steel so as to obtain the necessary mechanical and machining properties, and at the lowest cost, are described.—B. G. B.

Machinability. (*Steel*, 1953, **133**, Oct. 12, 135–136). Recent steps for improving machinability of steels without detriment to mechanical properties, are outlined. Main interest is in steels with lead additions which are reported to improve machinability by 25–60%.—D. L. C. P.

CLEANING AND PICKLING

Inhibitors vs. Accelerators—The Theory and Use of Acid Inhibitors and Accelerators. W. Billingsley. (*Wire and Wire Products*, 1953, **28**, July, 679–680). Some advantages of inhibitors and foaming agents in pickling baths are pointed out.

Inhibitors vs. Accelerators—Acid Pickling and Depolarizers. J. T. Irwin. (*Wire and Wire Products*, 1953, **28**, July, 680–681). The author points out some of the economics achieved by adding depolarizers to pickling baths.—R. A. R.

Inhibitors vs. Accelerators—Inhibitors and Adjuncts. A. Douty. (*Wire and Wire Products*, 1953, **28**, July, 681, 717–719). The functions of inhibitors and accelerators in pickling baths are explained.—R. A. R.

The Sodium Hydride Process—A New Method of Descaling Metals. N. L. Evans. (*J. Inst. Prod. Eng.*, 1953, **32**, June, 280). A short account of this process is given. The bath used consists of molten caustic soda containing 2% sodium hydride and which is heated at 350–370° C. It is suitable for use with cast iron and steel of all types.—B. G. B.

Continuous Pickling and Rolling of Wide Strip of Mild Basic-Bessemer Steel. P. de Lattre. (*Usine Nouvelle*, 1953, **9**, June 4, 31–35). Continuous operation demands very rapid pickling with strong sulphuric acid (250 g./litre) close to boiling point. This fact, and the large reductions undergone, necessitate the use of a steel as homogeneous as possible. Copper and chromium are found to minimize chemical heterogeneity in Bessemer steels whilst physical heterogeneity and ageing are lessened by the maximum possible elimination of gas and thorough deoxidation.—A. G.

Why and How Wire is Pickled. F. Kohlhase. (*Draht, English Ed.*, 1953, Sept., 47–48). Formulæ for pickling baths and recommendations on the cleaning of rod are given. Brief mention is made of mechanical descaling.—J. G. W.

Researches on the Buffing. Yukio Tanaka and Yoshinobu Tanaka. (*Tech. Rep. Osaka Univ.*, 1953, **3**, Mar., 11–20). [In English]. The effects of buffing time, prefinishing, and buffing pressure, on surface brightness were investigated. Preferred buffing compounds are classified for rough, medium, or mirror finishes on iron and steel, copper, brass, and aluminium.—K. E. J.

PROTECTIVE COATINGS

The Testing and Maintenance of Electroplating and Processing Solutions. (*Australasian Plating and Fin.*, 1951, **1**, Dec., 11–12 ; 1952, **2**, Feb., 7–8). These notes are intended to help the plater to maintain his solutions in good working order by regular checking and maintenance.—R. A. R.

Graphical Calculation of the Metallic Deposits Obtained by Electrolysis. J. Breuil. (*Chim. et Ind.*, 1953, **70**, Aug., 208–212). The techniques of electrolytic deposition are well established and serve many branches of industry. A simplified method of calculating such factors as efficiency, and weight and thickness of metal deposited, using nomograms, is described with the aid of an example.—A. G.

Gas Plating Offers Versatility. (*Steel*, 1953, **133**, Oct. 19, 120–124). The present scope of gas plating by the dry deposition of metal from vapour is described.—D. L. C. P.

Precoated Metals. (*Steel*, 1953, **133**, Oct. 12, 156–157). Precoated metals are available in the U.S.A. in a variety of base metals and coatings, and can free fabricators from plating operations. Steel strip may be covered with a variety of metals, plastics, and lacquers ; the properties and uses of these are given in a table.—D. L. C. P.

Practical and Comparative Study of Some Processes for the Preparation of Cast Irons before Coating by Electrolysis or by Immersion in Molten Metals. G. Lerouge. (*Metaux-Corrosion-Indust.*, 1953, **28**, July-Aug., 302–318 ; Sept., 348–369). A comprehensive investigation into the problems of the successful coating of cast irons with other metals is reported. Four types of cast iron have been considered ; these are normal, innoculated pearlitic, spheroidal graphite, and European malleable types. The effectiveness of various methods of surface preparation has been studied. The methods include immersion in a molten bath of zinc and sodium chlorides or sodium and potassium nitrates, the Kolene-Heurtey electrolytic treatment, and electrolysis in a cold aqueous solution of sodium hydroxide and cyanide. The application of three kinds of metal coatings to cast iron is discussed. These are electrolytic deposition of copper, nickel plating, and hot dipped tinning. Photomicrographs of various irons and coatings show the effect of different methods of treatment. The results of a large number of tests carried out on the coatings are given and all the results are summarized in tabular form.—B. G. B.

Chromium Plating in Steel Plants. J. B. Allen and J. D. Tulloch. (*Iron Steel Eng.*, 1953, **30**, Sept., 90–94). Although reference is made to nickel and copper depositions, the authors concentrate on chromium plating which has been successful in increasing the service life of heavy equipment. Chromium plated rams and cylinders of presses are described as well as plated roll-balance plungers, shear rams, ingot tilter plungers, and other parts of rolling mills and forges.—M. D. J. B.

On the Problem of the Wear Resistance of Chromized Surfaces. N. S. Gorbunov and V. P. Lazarev. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **86**, (2), 345–347). The wear resistances of Armco iron and chromized Armco iron surfaces were compared by a scratch hardness test and microhardness tests which showed the increased wear resistance obtained.

Resistance to Wear of a Carbon Steel, After Diffusion Chromizing During Friction in the Presence of Some Liquid Media. M. M. Khrushchov, M. A. Babichev, and G. N. Dubinin. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **92**, (2), 303–306). [In Russian]. The dependence of the resistance to wear of carbon steels whose surfaces were saturated with chromium by diffusion, on carbon content, hardness of surface layer, and properties of the liquid medium present on the friction surface was investigated. Distilled water and solutions of potassium chromate were used as liquid media.—V. G.

Substitute Coatings to Overcome the Scarcity of Nickel. H. W. Dettner. (*Metalloberfläche*, 1953, **7**, May, B72–B74). A survey is made of processes used for the electrodeposition of alloys intended as substitutes for nickel plating.—L. D. H.

How One Plater Beat Nickel Shortage. (*Steel*, 1953, **133**, Sept. 21, 174–175). The sequence of operations in an automatic copper-nickel-chromium plating line for tubular furniture parts is given. The copper base was adopted to allow a thinner nickel layer during the shortage.—D. L. C. P.

Galvanizing of Small Metal Parts. G. Steiner. (*Brown Boveri Rev.*, 1952, **39**, Nov.-Dec., 452–454). An installation is described with which it is possible to centrifuge small parts immediately after galvanizing. A saving in labour, good surface finish, and economy in zinc are the advantages claimed.—A. D. H.

The Distribution of Aluminium in Industrial Galvanizing Baths. N. B. Rutherford. (Brit. Non-Ferrous Met. Res. Assoc.: *Sheet Metal Ind.*, 1953, **30**, Aug., 657–660, 680). Experiments are described in which the distribution of aluminium in two industrial galvanizing baths was determined. Various amounts of aluminium were added during the measurements, and the resulting rates of levelling out of concentration differences were studied. The samples were taken from various depths, and spectrographic analysis was used to determine aluminium and iron contents. Although horizontal diffusion of aluminium is rapid, persistent vertical segregation may also occur. (18 references).—P. M. C.

The Future of General Galvanizing. R. L. Stubbs and A. R. L. Chivers. (*Metal Ind.*, 1953, **82,** June 26, 527, 528). Hot-dip galvanizing consumes about one third of all the zinc used in the United Kingdom, and about half of this is taken up by general galvanizers. The acute zinc shortage since the war is reviewed and the future prospects of the galvanizing industry are discussed. Possible competitive methods for protecting steel, (aluminium coating and painting), are considered, and indications are given of some fields in which galvanizing could be more widely used.—P. M. C.

Second International Conference on Hot Dip Galvanizing Held at Düsseldorf 30th June–4th July 1952. (*Zinc Development Assoc., July*, 1953). This 238-page volume contains an account of the proceedings of the above conference with revised texts of the papers presented and of the discussions on them. Abstracts of the papers follow :

The Ductility of Hot Dip Galvanized Coatings. H. Bablik, J. Krystof, F. Götzl, and R. Kukaczka. (1–16). The influence of the crystallographic orientation of the zinc coating on its ductility is discussed and the possibility of controlling orientation is pointed out. Ductile coatings are obtained when the basal plane lies at a large angle to the underlying steel. The adhesion of zinc is lower when a brittle Fe–Zn alloy layer is formed.—A. D. H.

The Flaking of Hot Dipped Zinc Coatings. M. L. Hughes. (17–42). Flaking consists of the detachment of a flake of η-zinc attached to blocks of Fe–Zn alloy. The elimination of η prevents flaking. A force of 2–5 tons normal to the steel face is necessary to detach a coating, the plane of separation being generally at the steel surface, or in thick coatings failure occurs in the δ or η zones.—M. L. H.

The Potential Behaviour of the Iron–Zinc Alloy Layer of Galvanized Steel in Various Hot Aqueous Solutions. R. C. Weast. (43–57). A study has been made of the potential of the zinc alloy layer in solutions containing HCO_3, SO_4, SiO_2, Ca, and NO_3 ions within the limits found in domestic supplies. The alloy layer is cathodic to steel and zinc and becomes more cathodic as the temperature increases. The alloy layer becomes more anodic as the concentration of oxygen is reduced below the saturation value. The alloy potential is sensitive to small changes in the concentration of the corroding solution.—A. D. H.

The Effect of Aluminium and Iron on the Structure of Galvanized Coatings. M. A. Haughton. (58–87). The effect of 0–0·2% Al in a laboratory-scale galvanizing bath was studied at 450° C. using dipping times of 1 and 5 min. with and without bath agitation. Variation of iron content in an aluminium-free bath was without effect on the structure of the coating or upon the rate of attack of steel in the bath. The addition of 0·05% Al gave smoother, brighter coatings, but bare spots were visible due to imperfect wetting of the steel. The structure of the coating was modified by 0·1–0·2% Al, and in low-iron baths the layer consisted only of Fe_2Al_5 and attack on the steel was reduced. With higher iron contents, heavy attack occurred on the steel and a heavy duplex columnar layer was formed. A similar effect was obtained with 0·2% Al, but the protective film of Fe_2Al_5 was thicker so that the attack on the steel was lower. Baths containing 0·1–0·2% Al gave erratic results depending upon detailed experimental conditions.—A. D. H.

A Galvanizer's Views on Bath Heating and Operation. E. McI. Wilson. (88–114). The author sets out an ordinary galvanizer's requirements to show what conditions must be met by plant manufacturers. A questionnaire is given which enables the galvanizer to specify his requirements completely. The specifications of two manufacturers fulfilling the required conditions are compared.—A. D. H.

Top Heated Galvanizing Bath at Virsbo, Sweden. N. Thoren. (114–120). A description is given of a galvanizing bath heated by the radiation from electrical resistance coils mounted above it. It is lined with firebrick. Advantages claimed are smaller dross production and the elimination of pot damage.—A. D. H.

Observations on the Attack of Molten Zinc on Iron. R. Haarmann. (121–146). The author reviews available information on the attack of iron by molten zinc with reference to the wear of galvanizing pots. Three types of attack are found : Flaking, pitting, and grain boundary penetration.—A. D. H.

Flux Techniques and Hot Galvanizing Economies. A. T. Baldwin. (147–156). The reasons which led to the development of zinc ammonium chloride ($ZnCl_2 \cdot 3NH_4Cl$) containing organic additions as a flux blanket on galvanizing baths are given. It is claimed that reduced dross formation, better adherence of the coating and increased throughput result from the use of this process. No more than 1 lb. of Al per ton of zinc can be added to the bath.—A. D. H.

The Galvanizing of Cast Iron. W. Montgomery. (157–166). The metallurgical characteristics of grey cast iron are briefly considered in relation to galvanizing. To obtain satisfactory coatings, shot blasting followed by a short dip in HCl is recommended. Acid pickling alone must be carried out carefully to minimize exposure of graphite flakes.—A. D. H.

Some Notes on the Recovery of Zinc from Galvanizers' Ash. N. B. Rutherford. (167–176). After briefly reviewing industrial methods for recovering zinc from galvanizers' ash, the B.N.F.M.R.A. process is described. The ash is plunged below the surface of a molten galvanizing bath and 70–80% of the metallic ash in the dross can be recovered. In comparison with other methods there is an appreciable saving in costs with greater efficiency of zone recovery.—A. D. H.

The Treatment of Pickle Liquors. A. R. L. Chivers. (177–197). The unwelcome effects arising from the discharge of spent pickle liquors into rivers or sewers are described and methods of treatment of effluents containing HCl and H_2SO_4 are discussed. A description is given of current British practice in neutralization plants.—A. D. H.

The Economics of Galvanizing. F. C. Braby. (198–207). The total costs of galvanizing are discussed with detailed reference to raw materials, labour, and overhead charges. The most important factor is the efficiency with which zinc is used.—A. D. H.

Working Conditions in Job Galvanizing Plants. H. T. Eatwell. (208–220). An account is given of the improvements in welfare and general working conditions made in a British galvanizing plant.—A. D. H.

Trends in Hot Dip Galvanizing. R. W. Bailey. (221–233). A review is made of developments in the galvanizing industry during the past 20 years showing that batch processes are being replaced by continuous operations. Present trends are discussed with reference to the papers presented at the Conference.—A. D. H.

Investigations of the Preece Test. H. Bablik. F. Götzl, and E. Nell. (*Metalloberfläche*, 1953, **7,** May, A66–A72). The Preece test was applied to galvanized coatings of various compositions, produced by different processes. It was confirmed that the solution velocity varied with the iron-zinc phase, the compactness of the coating, the process of manufacture, the presence of other constituents, and the degree of oxidation of the outside layer.—L. D. H.

The Formation of Hot Dipped Zinc Coatings. M. L. Hughes. (*B.I.S.R.A. Paper* MW/C/37/53 : *Product Finishing*, 1953, **6,** Aug., 49–62). The author discusses the interaction between steel and molten zinc and the formation, structure, and composition of alloy layers as affected by the composition and surface characteristics of the steel and the composition and temperature of the zinc and the period of immersion.—J. P.

The Manufacture of Tinplate. E. A. Lancaster. (*Canad. Metals*, 1953, **16,** July, 16–18). This is a brief account of tinplate production mentioning the two methods of coating with tin—hot dipping and electrolysis. The advantages of the latter method are enumerated.—J. C. B.

Complex Fluorides for the Deposition of Tin and Tin Alloys. A. E. Davies, R. M. Angles, and J. W. Cuthbertson. (*Trans. Inst. Met. Finishing*, 1953, **29,** Advance Copy No. 7). Recent work on the deposition of tin from stannous fluoborate electrolytes is described with reference to the effect of addition agents, anode sludging and electrode efficiencies and preliminary work on the deposition of tin from stannous fluosilicate baths is outlined.—J. P.

The Case for Tin-Nickel Alloy Plating. J. W. Cuthbertson. (*Metal Ind.*, 1953, **83,** July 31, 89–91). Tin and nickel can now be co-deposited as a single-phase alloy containing about 65% Sn and 35% Ni. The author discusses both the practicability of the process and the advantages it has to offer.

New X-Ray Gauge Checks Tin Plate Thickness. F. A. Behr. (*Non-Destructive Test.*, 1953, **11,** July, 33–36). Details are given of an instrument developed by North American Philips

Co. Inc. in co-operation with the U.S. Steel Co. An X-ray beam is directed upon the surface of the tinned sheet, the tin layer is penetrated, and the underlying steel emits fluorescent rays whose intensities are measured by Geiger counters. The fluorescent rays pass through the tin coating, and their intensity can be expressed as a logarithmic function of tin thickness. The equipment is calibrated against known tin thicknesses, and results are printed on a tape. Accuracy is of the order of $\pm 2\%$.—P. M. C.

Chemical Treatments for the Protection of Tinplate. E. S. Hedges. (*Echo Mines*, 1953, June, 395–396). Certain protein foods decompose partially during sterilization liberating sulphur which attacks tinplate. A review of chemical methods designed to prevent this attack is given. The latest process employs an oxidizing solution containing 1% sodium hydroxide and 0·3% sodium chromate with a trace of wetting agent. The time of immersion is 3 sec.—A. G.

Iron Plating from an Alkaline Bath. E. F. Foley, jun., H. B. Linford, and W. R. Meyer. (*Plating*, 1953, **7,** Aug., 887–893). Some preliminary results are reported on the effects of composition of an alkaline iron plating bath on cathode efficiency and operating characteristics. The optimum composition and operating conditions were found to be : Iron content (ferric) 20 g., sodium hydroxide 100 g., triethanolamine 154 g., tetrasodium ethylenediaminetetracetate 132 g. per litre ; temperature 180° F., c.d. 20 amp./sq. ft.—J. P.

Modern Industrial Rhodium Plating. R. Pinner. (*Electroplating*, 1953, **6,** Aug., 276–281). The equipment and processes for rhodium plating for decorative purposes, for highly reflecting surfaces and for electrical contacts is described.

Microhardness of Silicon Coatings Obtained by Diffusion. N. S. Gorbunov, A. S. Akopdzhanyan, and N. A. Izgaryshev. (*Doklady Akademii Nauk S.S.S.R.*, 1953, **91,** (2), 285–286). [In Russian]. The microhardness of coatings obtained by the diffusion of silicon at 1000° C. in 2 hr. in steels with various carbon contents was studied. The microhardness of the silicon-diffused layer on low-carbon steel does not differ materially from the microhardness of the original steel. The microhardness of coatings increases with increasing carbon content.—V. G.

Progress in the Field of Phosphatizing. H. Keller. (*Metalloberfläche*, 1953, **7,** Sept., A129–A136). A survey is made of the use of phosphatizing, as a protective layer, in the cold extrusion of steel, as a lubricant, and as an insulating layer in electric motors and transformers. A summary of the underlying principles in each case and an outline of present trends of development are given.—L. D. H.

Phosphate Coatings on Steel Surfaces. H. A. Holden. (*Metallurgia*, 1953, **48,** Aug., 71–77, 90). Several proprietary solutions are now available for the production of a range of phosphate coatings. The different types of coating and their application in the fields of corrosion protection, wear prevention, and cold-working lubrication, are discussed.—B. G. B.

Observations on the Electrostatic Application of Coatings. F. Bollenrath. (*Metalloberfläche*, 1953, **7,** June, B85–B89). A survey is made of the history and present state of knowledge of this process, by which a lacquer or similar material in a state of fine suspension is attracted electrostatically to the work to be treated. Principles and typical layouts are discussed, and experimental plants in Germany are described.—L. D. H.

Interior Lacquering of Sheet Metal Containers. O. Merz. (*Metalloberfläche*, 1953, **7,** June, A90–A92). A survey is given of the applicability of a number of plastics to the lacquering of metals.—L. D. H.

Sheet Lacquering. H. Weise. (*Metalloberfläche*, 1953, **7,** June, B89–B93). An outline is given of the various techniques for the preparation, lacquering and after-treatment of sheet metal.—L. D. H.

Protection of Metallic Surfaces by Polyethylene. (*Echo Mines*, 1953, June, 415–416). The chemical and physical properties of polyethylene films, which include low density, flexibility, and almost total chemical resistance at normal temperatures, are outlined.—A. G.

New Resin Linings Give Better Container Protection. D. E. Hartman. (*Iron Age*, 1953, **171,** June 11, 129–132). A new epoxy resin lining for metal containers has been developed. It is non-toxic, resistant to most acids and oils and withstands the cracking, scratching, denting, and other physical abuses containers normally meet. Linings of from ¾ to 1 mil dry coating thickness is adequate for new steel and is baked on at 250°–500° F. For reconditioned drums two coats are recommended.—A. M. F.

Electric Spark Hardening of Metallic Articles. G. P. Ivanov and N. D. Titov. (*Liteinoe Proizvodstvo*, 1953, **3,** 1, 21–22). [In Russian]. The Ivanov electric metallizing machine and its use for depositing hard materials on steel or cast iron surfaces are described. From a primary voltage of 220 a pulsating and adjustable secondary voltage produces a spark which carries particles of the hard material (anode) on to the article (cathode). The hardness of the deposited layer is enhanced by the nitriding of the particles as they pass through atmospheric nitrogen, ionized by the spark. The high temperature of the spark also favours diffusion and leads to firm adhesion of the deposited layer. Photomicrographs of treated surfaces are shown.—S. K.

Corrosion Protective Packings. F. Ohl. (*Metalloberfläche*, 1953, **8,** Aug., A121–A124). A description is given of some modern developments in corrosion protective packings and sprayed coatings, with a reference to the cocoon process.

Uses of Sprayed Metal Coatings. (*Product Finishing*, 1953, **6,** May, 68–76). The position of metal spraying in industry is reviewed and the properties of aluminium and zinc coatings for protection of steel against atmospheric or immersed corrosion are discussed. The types of paint which show promise for use as additional protection over sprayed metals are indicated.—J. P.

Recent Advances in Metal Spraying by the Wire Process. W. E. Ballard. (*Trans. Inst. Met. Finishing*, 1953, **29,** Advance Copy No. 4). Recent developments, more particularly with respect to pistol design and the use of automatic spraying equipment, are described.—J. P.

Recent Developments in Metal Spraying by the Powder Process. W. McDermott. (*Trans. Inst. Met. Finishing*, 1953, **29,** Advance Copy No. 3). The general principles of metal spraying by the powder process are described and an account is given of an improved spraying pistol which allows the application of denser, less oxidized, and more adherent coatings of zinc and aluminium, than does the older design. A simple quantitative adhesion test is described. Some recent specialized techniques and applications are outlined, including the production of coatings of very low and very high resistivity, the spraying of steels, ' aluminizing ' by spraying and heat-treating, production of hard, non-porous surfaces by melting of special sprayed alloy coatings, and production of improved deposits of zinc and aluminium on a basis metal pretreated by steel spraying or by heating.—J. P.

Stainless Steel Spraying of Drums and Shafts in the Chemical and Food Industries. (*Electroplating*, 1953, **6,** July 267–271). Some of the advantages to be gained by using sprayed, ground, and polished stainless steel for the protection of machine components coming in contact with corrosive and abrasive preparations are described.—J. P.

Coating Takes on Life Saving Rôle. (*Steel*, 1953, **133,** Sept. 28, 90). Sprayed molybdenum wire is now being used as a finish for building up wear surfaces, and salvaging equipment. The product, ' Sprabond ', can be easily applied and it combines hardness with lubricant-holding porosity.—D. L. C. P.

Porcelain Enamel: Orphan of the Metal Finishing Industry. E. M. Smith. (*Metal Finishing*, 1953, **51,** Aug., 71–74). The composition and properties of enamelling steels and their preparation for enamelling, and the composition, application and firing of the enamel are briefly described.—J. P.

The Strains in Vitreous Enamels Fired on Metals. H. Moore. (*Inst. Vitreous Enamellers Ltd., Bull.*, 1953, **4,** June).

Symposium on Enamelling of Cast Iron. (*Proc. Inst. Vitreous Enamellers*, 1950–52, **10,** 63–73). The following papers were presented at this Symposium, held at the 1951 Spring Meeting.

Foundryman Enameller's Viewpoint. K. E. Walker. (64–66).

Gases in Iron and Steel. J. E. Hurst. (66–68).

Foundry Point of View. F. H. Hoult. (68–69).

Metallurgical Considerations. W. J. Colton. (69–71).

Ball Clays—Some Aspects of Their Use in the Suspension of Enamel Slip. H. W. Webb. (*Proc. Inst. Vitreous Enamellers*, 1950–52, **10,** 25–30).

Suspension and Biscuit Strength of Titanium Enamels. H. Laithwaite. (*Proc. Inst. Vitreous Enamellers*, 1950–52, **10,** 31–38).

Lithium in Vitreous Enamellers. S. Hallsworth. (*Proc. Inst. Vitreous Enamellers*, 1950–52, **10,** 39–44).

Design for Vitreous Enamelling. II—Production of Castings for Subsequent Vitreous Enamelling. W. Todd. (*Proc. Inst. Vitreous Enamellers*, 1950–52, **10**, 47–48).

Maintenance Painting of Steel and Coke-Oven Plants. S. C. Frye. (*Iron Steel Eng.*, 1953, **30**, Sept., 83–88). The importance of painting as a recognized tool of preventive maintenance is stressed. The painting of outside as well as inside equipment and plant is described, particularly blast-furnaces, coke-oven plants, hot stacks, roofs, tanks, interior of buildings, and machinery. Consideration is also given to paints and surface preparation.—M. D. J. B.

Surface Defects in Steel and Their Importance in the Application of Paints. A. Roos. (*Peintures, Pigments, Vernis*, 1953, **29**, June, 474–484). The surface phenomena which modify the nature of the surface are reviewed. Various defects in steels are discussed in the light of the physical chemistry of surfaces. The factors promoting corrosion of steels and the influence of pickling and pickling 'blisters' on the application of paints are considered.—A. G.

Surface Investigations of Paint Coatings, Produced by Cold and Hot Methods. R. Klose. (*Metalloberfläche*, 1953, **7**, June, A81–A89). The properties of coatings of lacquer produced by cold and hot spraying are reported.—L. D. H.

Measurement of the Size-Distribution of Spray Particles. L. K. Wheeler and E. S. Trickett. (*Electronic Eng.*, 1953, **25**, Oct., 402–406). The apparatus designed uses a phototelegraph transmitter to scan spot patterns produced by a spray. The resultant signals, which are proportional in duration to the chord lengths, are presented to a discriminating device which records the numbers of chords exceeding predetermined limits. The apparatus was developed at the Post Office Engineering Research Station.—J. C. B.

A Study of the Electrostatic Spray Coating Process with a Spray Head. K. Tamura. (*J. Mech. Lab.*, 1953, **7**, Mar., 41–49). [In Japanese]. Data were obtained concerning the charge and diameter of paint particles, and rotation and potential of the spray head. The electrostatic process has similar applicability to coating articles to the conventional spray gun, and shows some advantages.—K. E. J.

POWDER METALLURGY

The Manufacture of Components from Powdered Metals. W. D. Jones. (*J. Inst. Prod. Eng.*, 1953, **32**, June, 271–279). A fairly detailed description of the production of articles from metal powders is given. The advantages and disadvantages of the technique are explained. The design of dies and the limitations in their design are explained.—B. G. B.

New Process Gives Unusual Powder Parts. H. J. Hamjian and F. N. Darmara. (*Iron Age*, 1953, **172**, July 30, 98–100). A new powder metallurgy method developed by the Utica Drop Forge and Tool Corp. can be used for forming complicated shapes. Fine powders are compacted and presintered between 1500° and 1800° F. for preliminary machining before final sintering process.—A. M. F.

High Strength Precision Iron Powder Parts. W. J. Doelker and H. T. Harrison. (*Mat. Methods*, 1953, **38**, July, 67–71). The availability of soft electrolytic iron powder with highly controlled properties has made possible the production of high quality, high strength parts in large quantities, with important reductions in both production and tool costs. The general specifications for such powder, and the properties, tolerances, and excellent surface finish of the pressed and sintered products are discussed.—P. M. C.

Some Experimental Data on Sintered Hard Carbides. V. Chiaverini. (*Bol. Assoc. Brasil. Met.*, 1953, **9**, Jan., 5–20). [In Portuguese]. Sintered carbides are classified according to their use. The mechanism of sintering is described and properties of carbides from the U.S.A. are tabulated.—R. S.

Methods of Regulating the Surface Activity and Their Principal Importance for Powder Metallurgy and Powder Ceramics. J. A. Hedvall. (*Arkiv för Kemi*, 1953, **6**, (3), 241–350). [In English]. Some results are presented of the influence of disturbances in the structure or in the state of energy of the lattice on the physicochemical properties of the surface. The subjection of metals to supersonic radiation facilities the formation of tarnishing layers; this effect is not caused by a rise in temperature, but solely by the supersonic waves. Dissolved gases disturb the lattice and affect surface potential. The adsorption capacity of a ferric oxide preparation declines more rapidly after preliminary heating in nitrogen than after heating in oxygen.—R. A. R.

PROPERTIES AND TESTS

A Mathematical Equation for the Stress-Strain Curve in Tensile Testing. A. Krisch. (*Arch. Eisenhüttenwesen*, 1953, **24**, Sept.-Oct., 401–405). The stress-strain function $\sigma = \alpha\,\epsilon^n$, proposed by Fusfeld and by Kostron, does not permit the 0·2% yield point of materials to be calculated; it has been modified by a correction factor $(1 + u.\epsilon^r.v)$. The constants are chosen so that the function shows a small fixed deviation from actual behaviour at the maximum stress point. With this function, the small deformations during tensile testing can be calculated and the stress-strain curve computed from the usual measured values (0·2% yield point, tensile strength, elongation and reduction of area). For a series of alloyed and unalloyed heat-treatable steels, the change of work-hardening index for small deformations of 1% up to the limit of uniform extension has been followed as a function of annealing temperature. For deformations less than the limit of uniform extension, the work-hardening index is many times that at the limit itself.—J. P.

Effect of the Design of a Testing-Machine on the Form of the Static Tensile Curve. P. G. Kirillov. (*Zavodskaya Laboratoriya*, 1950, **16**, (8), 1019–1020). [In Russian]. A new tensile testing machine, suitable for static tests at high temperatures is described, and some results obtained with it and with conventional machines are presented and compared. The load is suspended from a dynamometer, having a negligibly small travel, which can be lowered at a given rate. This rate can be considered equal to the rate of deformation of the specimen on which the load acts, and the effective force to the difference between the load and the dynamometer reading.

Directionality Affects Physical Properties of Wrought Metals. H. A. Unckel. (*Iron Age*, 1953, **172**, Sept. 10, 170–173). The effects of directionality in wrought alloys on their mechanical properties are reviewed. Strength, ductility, impact and fatigue properties are affected in varying degrees depending on the metal and working process used. Slag and oxide inclusions, segregation and intermediate phases are believed to decrease ductility with ensuing stress concentration and crack-propagation. Grain alignment by preferred orientation due to excessive cold working may also reduce ductility. (14 references).—A. M. F.

Mechanical Anisotropy in Some Ductile Metals. W. A. Backofen and B.B. Hundy. (*J. Inst. Metals*, 1953, **81**, May, 433–438). Fracturing specimens in tension after prestraining in torsion has shown that a fibrous structure of flaws, which behave like cracks, exists in 70 : 30 brass, nickel, Monel metal, and Armco iron. Before the presence of the crack structure becomes apparent, however, the maximum shear strain introduced by twisting must exceed a critical value that varies from about 1 to 2·5, depending upon the metal and whether prestraining is followed by annealing.—R. A. R.

The Bend Yield Point, an Additional Characteristic for Thin Sheets. W. Fackert. (*Arch. Eisenhüttenwesen*, 1953, **24**, Sept.-Oct., 407–410). The construction and operation of an apparatus for determining the bend yield point of thin sheets is described. A strip 25-mm. wide is clamped on a table and a projecting end is gradually bent, by an increasing weight applied to a lever pivoted at the edge of the table, until the specimen 'gives' suddenly. The bend yield point is calculated from the load and the angle at which the specimen yields. The equipment gives reproducible results.—J. P.

Units for Measuring Variations in Measurements. W. J. Youden. (*Metal Progress*, 1953, **64**, Sept., 91–96). A short introduction to the use of statistics in investigating the variations obtained in the measurement of properties of materials is presented.—B. G. B.

Million-Pound Calibrators. (*Steel*, 1953, **133**, Sept. 14, 122–127). The development of load calibration devices by the National Bureau of Standards for standardizing the largest existing testing machines is described. This includes the design of compression dynamometers with wire-resistance strain gauges as part of their load indicating systems. The dynamometers have a capacity of 3×10^6 lb.

The Behaviour of Steels with Different Notched Bar Impact Strengths during Deformation under Multi-Axial Stresses. H. Bennek, E. Houdremont, and R. Mailänder. (*Arch. Eisenhüttenwesen*, 1953, **24**, July/Aug., 315–321). Steels, which on normal tensile testing show equal yield point, ultimate strength and elongation, may exhibit brittle or tough fracture in the

notched-bar impact test. Investigations, mainly on heat treatable steels, have shown that the difference will also exhibit itself in the tensile test if multidimensional stress is applied during necking. The difference becomes more marked if the testing conditions are made more severe, *e.g.*, by lowering the testing temperature. According to results of expansion and bulging tests, a state of two-dimensional stress (with equal principal stresses) suffices to cause transition from tough to brittle fracture. Internal pressure tests on tubes of Ni–Cr steels have shown that the transition can occur without reduction of tensile strength or peripheral extension, whereas with the less tough Cr–Mn–Si steels brittle fracture occurs at smaller deformations and correspondingly lower tensile strengths. The transition from tough to brittle fracture need not therefore be linked with a decrease in deformation before fracture and reduction of tensile strength. Only on increasing the severity of the test or with a much reduced toughness does premature fracture occur. The reported influence of tendency to brittle fracture on fatigue strength and notch susceptibility in vibration and repeated impact tests was not detected. The fatigue limit for the brittle state was lower than that for the tough state. This difference is because cracks can lead to breakage more easily in the brittle than in the tough state. In general, the investigation has confirmed the fact that the tendency to brittle fracture which is exhibited in the notched-bar test can also show itself under conditions of static multi-dimensional stress.—J. P.

Concerning the H. M. Schnadt Notched Bar Impact Test. A. Krisch. (*Stahl u. Eisen*, 1953, **73,** Sept. 10, 1215–1225). It can be shown that the theory of the Schnadt impact test may be derived from the shape variation energy hypothesis. The index π used by Schnadt to characterize the state of stress and tendency to plastic deformation is the ratio σ_V/σ_1, where σ_V is the stress required to start flow and σ_1 is the greatest principal stress. The Schnadt testing technique is not new ; work was carried out in 1921 on specimens with notches of various diameters. The method by which Schnadt correlates impact strength with notch diameter is adversely criticized.—J. P.

Judgment of the Notch Toughness of Materials from Mechanical Testing Results. M. Watanabe and S. Goda. (*Tech. Rep. Osaka Univ.*, 1953, **3,** Mar., 159–170). [In English]. Experiments at low temperatures on four rimming steels disclosed relationships between notch toughness and load/elongation or load/deflection ratios derived from normal tensile tests. A method of evaluating notch toughness of low carbon steels by room temperature tests is therefore tentatively proposed.—K. E. J.

The Influence of Heat Treatment on Critical Stresses. K. Lötsch. (*Maschinenbau u. Wärmewirt.*, 1953, **8,** Feb., 45–52). The influence of hardening, tempering and annealing a medium carbon (1·1% Mn, 1·3% Si) steel on its tensile, compressive, torsional, and notch impact strength was investigated.

Evaluation of Notch Plasticity on Half-Ring and Prismatic Specimens. Ya. B. Fridman, A. A. Bat' and T. A. Volodina. (*Zavodskaya Laboratoriya*, 1950, **16,** (8), 966–975). [In Russian]. A simple method for the evaluation of the sensitivity of metals to notching along and across the fibres during single static loading is reported. The method is based on the measurement of the notch plasticity of a notched specimen being bent by a static load, the plasticity being determined from the deflection in the plastic zone when the first crack appears. Deflection is found from the deformation diagram. For studying the transverse mechanical properties of small metal sections half-ring specimens are recommended. The method was tested on steels and some aluminium alloys at room temperature and at −70° C. In all tests the deflection changed more sharply than toughness. The proposed method has the following advantages over the usual evaluation of materials by toughness : (*a*) Notch plasticity is determined independently of the strength of the material, thus enabling materials of different strength to be compared ; (*b*) the use of half-ring specimens enables transverse notch-plasticity to be conveniently controlled in parts down to 15 min. in dia. ; and (*c*) the method is more sensitive than the normal determination of deformation on impact specimens. The method is time-consuming.—S. K.

A Novel Static Strength-Testing Machine. F. Müller-Magyari. (*Maschinenbau u. Wärmewirt.*, 1953, **8,** Jan., 1–5). After outlining the difficulties of applying a universal testing machine to large or complicated structures, and giving some examples of specially designed machines for the purpose, the author describes a machine suitable for the usual stress and strain measurements on plates, rods, frames, and scale models.—L. D. H.

Surface Effects in Plastic Deformation of Metals. A. F. Brown. (*Advances in Physics*, 1952, **1,** Oct., 427–479). Recent microscopical experiments suggest that it is in the later stages that deformation is concentrated on a few atomic planes whilst the first fractional per cent. of strain is much more nearly homogeneous. Theories accounting for the two stages are examined. It is shown that the surface finish affects not only the appearance of internal processes but also the processes themselves. In cases where the deformation is not homogeneous the balance of evidence is that it is also not continuous in time : instead, slip on an active slip plane tends to a limit which is reached either gradually or suddenly depending on the nature of the metal and the conditions of stress. It is shown that slip bands, the sources of hardening, are also places of weakness.—R. A. R.

On the Investigation of Internal Stress in the Case-Hardened Steel Bar. T. Ueda. (*Tech. Rep. Osaka Univ.*, 1953, **3,** Mar., 21–39). [In English]. The distributions of internal stress in carbon, Ni-Cr, and Cr–Mo steel bars, carburized by gas and pack methods, and heat-treated, were measured. The compressive stress is at a maximum near the surface, and vanishes at a point near the carburized-zone/core boundary. Stress then becomes tensile, reaching a maximum at the centre. The internal force is greatest with carbon steel, and least with Cr–Mo steel. Forces in gas-carburized bars are generally greater than those in pack-carburized bars.—K. E. J.

Brittle Fracture Colloquium, Leoben, 27–28 February, 1953. (*Radex Rundschau*, 1953, (4/5), May-June). The following papers were presented at the Conference held at the Montanistische Hochschule in Leoben :

Problems and Aims of the Brittle Fracture Colloquium. R. Mitsche (137).

Development and Present Position of the Brittle Fracture Problem. E. Houdremont. (138–150).

Fundamentals of Brittle Fractures in Steels. A. Legat. (150–152).

Brittle Fracture Phenomena in Welded Steels. (153–157).

Brittle Fracture in Welded Built-Up Girders. T. Povse. (157–162).

Brittle Fracture in Rails. R. Walzel. (162–168).

Brittle Fracture in Automobile Parts. K. Ullmann. (168–174).

Transition from Brittle to Tough Fracture in Iron-Silicon Alloys. F. Lihl. (178–185).

Fundamentals of the Theory of Brittle Fracture. A. Slattenschek. (186–199).

The Problem of Brittle Fracture. E. Siebel. (200–203).

Fundamentals of the Brittle Behaviour of Metals (Theory of E. Orowan). E. Schmid. (203–207).

The Physics of the Behaviour of Brittle Materials. A. Smekal. (208–212).

Brittle Fractures Initiated by Fatigue. F. Regler. (212–220).

Some Thoughts on the Atomistics of Brittle Phenomena. H. Nowotny. (220–227).

The Significance of the Free Path Length of Slip for Tough and Brittle Fracture. F. Rohner. (227–228).

Structural Heterogeniety, Mechanical Properties, and Brittle Fracture Behaviour with Al-Ti-Treated Structural Steels as an Example. R. Mitsche. (229–233).

Metallurgical Aspects Which Can Affect Micro-Inclusions of Slag in Steel. O. Krifka. (234–237).

Microstructural Condition and the Notch Toughness of Weldable Alloy Steels. H. Krainer. (238–245).

Microstructural Condition and Strength Properties of Constructional Steels. E. Plöckinger. (246–249).

Transformations and Volume Changes as the Source of Internal Stresses. M. Kroneis. (249–255).

Conditions Initiating Brittle Fracture in Welding. H. Hummitzsch. (256–262).

Some Metallurgical Considerations Regarding the Problem of Brittle Fracture in Weldable Steel St 52. O. Werner. (262–270).

The Problem of Brittle Fracture Tests. F. Rapatz. (270–276).

Survey of the Estimation of the Susceptibility of Steels to Brittle Fracture. H. Hautmann. (277–281).

Attempts to Produce Brittle Fracture. K. Wellinger. (282–287).

Some Aspects of the Initiation and Propagation of Brittle Fracture. C. Schaub. (287–292).

Explosive Brittle Fractures in Tool and Constructional Steels. O. Felgel-Farnholz. (292–299).

The Brittle Fracture Problem with Cold Rolled Deep-Drawing Steel. F. Montbrun and Herbiet. (300–303).

Brittle Fractures in Rolled Sections After Previous Stressing by Impact or Bullets. J. Wolff. (304–308).

Brittle Structural Failures with Emphasis on Welded Ships. J. O. Almen. (*Product Eng.*, 1953, **24,** Apr., 192–203). Service experiences and the results of experiments to support the theory that welded structures fabricated from ductile steel fail by brittle fracture are described. Data shows that the susceptibility to the several common causes of brittle fractures in ductile metal, such as fatigue, stress corrosion cracking, and biaxial tension, can be reduced by the development and retention of residual compressive stresses in vulnerable areas.—A. M. F.

Brittle Coatings for Use in Stress Analysis Under Varying Temperature Conditions. F. N. Singdale. (*Non-Destructive Test.*, 1953, **11,** July, 37–39). Brief details are given of the brittle lacquer method of stress analysis, and a newly developed type of brittle coating, called Stresscoat All-Temp, is described. The new coating is essentially a vitreous enamel which can be designed to have various specific threshold sensitivities, and is manufactured by the Magnaflux Corp. The coating will operate satisfactorily and accurately through a temperature range of −50 to 875° F. It is unaffected by water and oil.—P. M. C.

The Foil Strain Gauge. P. Jackson. (*Instrument Practice*, 1953, **7,** Aug., 775–786). Owing to the frequent failure of wire strain gauges, a foil strain gauge was designed. The design, construction, and mode of operation of the gauge are described, its modification for high temperature work is outlined, and lines of future development are indicated.

Photoelastic Stress Examination. F. K. Lightenberg. (*Lastechn.*, 1953, **19,** Sept., 139). [In Dutch]. The principles of photoelastic stress analysis us ingmodels of structures are briefly explained.—R. A. R.

New Photoelastic Equipment in the Laboratories of the Czechoslovak Academy of Science. M. Milbauer. (*Strojirenstvi*, 1953, **3,** (8), 612–615). [In Czech]. A description is given of new equipment for photoelastic stress determinations. Its design is discussed, and compared with similar equipment of foreign make.—P. F.

Etching Method for the Fatigue of Mild Steel (Report II) H. Yamanouchi and T. Inukai. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 50–51). [In English]. Changes of properties during fatigue tests may be followed by etching, and are explained theoretically. Temperature rises are discussed.—K. E. J.

Application of Ultrasonic Flaw Detection Method for Material Testing. I—Application to Fatigue Testing. M. Matsushiro, A. Hikata, and T. Yoshino. (*J. Mech. Lab.*, 1953, **7,** July, 140–145). A Reflectoscope ultrasonic crack detector working at 5 megacycles was applied during push-pull fatigue tests on round mild steel bars. Three types of crack propagation were observed.—J. G. W.

Shot Peening as a Process for the Surface Treatment of Machine Parts. O. K. Kowarsch. (*Maschinenbau u. Wärmewirt.*, 1953, **8,** Aug., 229–231). The author reviews the shot-peening process, discusses the basic principles, and points out the effect on the mechanical properties of various steels, in particular the improvement in fatigue properties.—L. D. H.

Effect of Diameter on Notch-Coefficient of Rotary Bending Test Piece. A. Ono. (*Proc. Japan Acad.*, 1951, **27,** Oct., 445–450). [In English]. Results of fatigue tests for carbon steel, in which the effects of specimen size on endurance limit and notch coefficient were studied, are analysed. A means of expressing the coefficient in terms of theoretical factors is deduced.—K. E. J.

Effect of Surface-Active Substances on the Fatigue-Limit of Metals. G. V. Karpenko. (*Zavodskaya Laboratoriya*, 1950, **16,** (8), 984–985). [In Russian]. In the experiments described, the fatigue-limits of specimens of a chromium and a carbon steel were determined in air and in various surface active substances. The fatigue limit of the chromium steel decreased by 16% and 44% respectively when the specimen was immersed in castor oil and a 2% aqueous solution of iso-amyl alcohol. For carbon steel in alcohol, the reduction was 15%. Almost the same effects were produced by 0·2% iso-amyl alcohol solution. Greater effect on fatigue limits was produced by surface active substances on ground and heat-treated, than on turned, specimens.—S. K.

The Cottrell–Bilby Theory of Yielding of Iron. T. Yokobori. (*Phys. Rev.*, 1952, **88,** Dec. 15, 1423). Some ambiguities concerning the method of deriving the equation of temperature and strain rate dependence are removed if an initial equation, based on consideration of yield as a Markoff process, is used. Results agree well with experimental data.—K. E. J.

Fatigue. H. L. Cox. (*J. Roy. Aeronaut. Soc.*, 1953, **57,** Sept., 559–565). The author discusses work carried out at the Mechanical Engineering Research Laboratories and the National Physical Laboratory to discover the causes of fatigue in metals. The materials used were mostly steels and aluminium alloys. The effect of stress concentrations was examined by using sharp notches and round holes in the test specimens. For the present, the author concludes that a fatigue crack is likely to start in a region of maximum stress range, and that it might develop in tension or shear with a slight preference for the former. The results of numerous tests are awaited and these will require statistical analysis.—J. C. B.

Fatigue from the Metallurgist's Viewpoint. E. R. Gadd. (*J. Roy. Aeronaut Soc.*, 1953, **57,** Sept. 565–580). The author presents an exhaustive literature review on the metallurgical causes which affect the fatigue strength of metals. (78 references.)—J. C. B.

Fatigue in Engine Design. F. M. Owner. (*J. Roy. Aeronaut. Soc.*, 1953, **57,** Sept., 580–584). The author examines factors affecting the fatigue strength of aircraft materials with respect to engine design. He concludes with six design maxims : (1) No sharp corners ; (2) err on the generous side with radii—they are seldom made too large ; (3) if possible avoid all sudden changes of section by introducing gradual blending ; (4) importance of surface treatment and finish ; (5) choice of material must take into account the degree of stress concentration present, and (6) proper care and maintenance in operation.—J. C. B.

Investigation of the Fatigue Resistance of Constructional Steel Test Bars Which Have Been Flame-Cut. F. Koenigsberger and Z. Garcia-Martin. (*Cien. tecn. Solda.*, 1953, **3,** July-Aug.) [In Spanish]. The influence of carburization or decarburization, hardening, contraction cracks, and internal stresses due to variation in temperature from the surface to the core after oxygen cutting, on the fatigue strength of constructional steels is compared with the effects of the same variables on the fatigue strength of steel test bars prepared by machining. The fatigue strength of the oxygen-cut specimens was 29% lower than that of the machined specimens. When no special precautions were taken to reduce tensile stresses induced by machining, the difference was only 7·5%. The main factors affecting the fatigue strength of oxygen-cut specimens are listed.—R. S.

Endurance of Helical Springs Related to Properties of the Wire. H. C. Burnett and C. L. Staugaitis. (*Metal Progress*, 1953, **64,** Sept., 77–81). The results of a number of tests on piano spring wire and springs wound from them are given. A correlation between the fatigue properties of piano spring wire, as determined by reverse bending tests, and the fatigue properties of helical compression springs wound from this wire has been found.—B. G. B.

Strength and Deformation of Low Carbon Steel Bars with a Round Crack under Static and Repeated Loads. T. Isibasi. (*Memoirs of the Faculty of Engineering, Kyushu University, Fukuoka, Japan*, 1951, **12,** (3–4), 381–308). [In English]. Fatigue tests were performed on circumferentially cracked specimens of low-carbon steel. Considerable plastic deformation occurred at the root of the crack at room temperature and at −10° C. The rate of increase in crack depth with increasing load increases. The fatigue limit of cracked specimens was reduced by annealing at about 600° C.

Residual Compressive Stress Strengthens Brittle Materials. J. O. Almen. (*Product. Eng.*, 1953, **24,** July, 189–911). Tests on springs have demonstrated the beneficial effects on fatigue life of the peening of the surface to induce residual compressive stresses.—A. M. F.

Procedure for Determining the Hardness Variation Pattern of Alpha and Gamma Phases in Steel Being Heated *in Vacuo* to 2000° F. M. G. Lozinskii. (*Doklady Akademii Nauk*, 1952, **84,** (1), 63–66). An apparatus is described with which the

changes in hardness can be determined of six small disc specimens while they are heated *in vacuo* to 1100° C. Some results for 0·20% and 0·35% carbon steels are presented. The use of the apparatus for determining the critical points is discussed.—R. A. R.

Loading Errors Through Vibrations in Hardness Measuring Instruments. F. Gärtner. (*Osterr. Masch. Elecktrowirtshaft*, 1953, **8**, Sept., 265–269). In considering high-speed hardness testing for quality control, it was found that the speed of application of the load had a negligible effect if variations of load due to vibration of the instrument were sufficiently low. This was the case if a spring-loading rather than a weight-loading type were employed.—L. D. H.

Relations between Micro- and Macro-Vickers Hardness Testing. R. Schulze. (*Trans. Instruments and Measurements Conf., Stockholm*, 1952, 281–294). [In German]. The increase in Vickers hardness numbers at small loads is explained by the fact that only plastic deformation is measured. Elastic deformation, important for microhardness measurements, was determined by evaporating a coat of aluminium on to the diamond before making the indentation. A formula is given which takes into account the plastic and elastic constituents of the indentation. Factors causing errors in reading and applying the load are discussed.—L. D. H.

The Need and the Conditions Required for Obtaining Internationally Comparable Rockwell-C Hardness Measurements. K. Meyer. (*Trans. Instruments and Measurements Conf.*, Stockholm, 1952, 256–266). [In German]. The author first discusses the sources of error in making Rockwell-C hardness measurements, giving the order of magnitude of the errors. He then gives a detailed description of instruments designed to measure these errors and describes a standard hardness tester.—L. D. H.

Evaluation of the Tendency of Metals to Cold-Hardening from the Shape of Indentations Produced During the Measurement of Their Hardness with a Pyramid Indentor. V. K. Grigorovich. (*Zavodskaya Laboratoriya*, 1950, **16**, (8), 980–983). [In Russian]. The special features of pyramid indentations are considered, and experiments are described in which the curvature of the sides of the indentation is related to the properties of the material. Two steels subjected to various preliminary deformations and heat-treatments were investigated. Indentations were produced under loads of 20, 50 and 62·5 kg. Curves are given showing the dependence of the degree of curvature on the relative diameter of the plastically-deformed zone. Changes in hardness and curvature are also shown in relation to tempering temperature. The shape of indentation produced on cold-deformed metals subjected to tempering gives a good idea of their tendency to cold hardening.—S. K.

Microhardness Testing and Its Practical Application. H. Tertsch. (*Radex Rundschau*, 1953, (3), Mar., 126–128). The necessity for distinction between single crystal hardness and multi-crystal-structure hardness is discussed, and suggestions are made for procedure to distinguish between the two in practice. Additional difficulties due to planes of cleavage or preferential breaking of crystals are mentioned.—E. C.

The Dependence of Hardness on the Testing Load. W. Späth. (*Metalloberfläche*, 1953, **7**, Mar., A39–A40). It is pointed out that in pyramid hardness testing, the hardness quotient is approximately constant in the load range of 3–30 kg. With smaller loads it rises to a maximum, then falls rapidly. The influence of roughness of the surface to be tested on the mechanism of the test is explained, and the variation in the hardness quotient interpreted.—L. D. H.

Comparison of Tests for Hardenability of Shallow-Hardening Steels. G. K. Manning. (*S.A.E. J.*, 1953, **61**, July, 30–36). A detailed account is given of a co-operative programme of tests, among ten laboratories, sponsored by the S.A.E. Iron and Steel Technical Committee Division V. Jominy end-quench and S.A.C. complete quench tests were done on a range of six S.A.E. shallow-hardening steels. The results are given and discussed in detail. Both test methods were shown to yield reproducible results.—P. M. C.

Fundamental Study on Making Standard Block for Hardness Measurement. I. Investigation of Standard Block Made by Shore Instrument & Mfg. Co. II. The Effect of Heat-Treatment Condition on the Hardness Distributions. T. Mitsuhashi, M. Ueno, and T. Hagiwara. (*J. Mech. Lab.*, 1953, **7**, May, 94–101 ; 102–109). [In Japanese]. Chemical composition, hardness distribution, microstructure, and accuracy of mechanical finishing were examined on standard blocks. Variations in hardness over the block surfaces are reported. These widen as hardness increases. The most suitable conditions for annealing, quenching, and tempering a block of eutectoid steel have been determined.—K. E. J.

A Theory of Work-Hardening of Metals. II. Flow Without Slip-Lines, Recovery, and Creep. N. F. Mott. (*Phil. Mag.*, 1953, **44**, July, 742–765). An earlier theory is extended. Fine and coarse slip both originate in Frank-Read sources, the former occurring when dislocations move slowly. The initial stages of deformation are by fine slip, and hardening is much slower than for coarse slip. In creep, deformation is by fine slip. β-creep is related to steady-state creep. (59 references).

Magnetic Measurements of Age-Hardening of Iron-Molybdenum Alloys. T. Mishima, R. R. Hasiguti, and Y. Kimura. (*J. Faculty of Engineering*, University of Tokyo, 1953, **24**, Jan., 25–26). [In English]. The internal strain as measured by magnetic properties was correlated with the atomic process of age hardening in the above alloys. The atomic process of ageing was studied by measuring the change of lattice constant and saturation magnetization, the latter being insensitive to structure. The fractional change (p) of these values, and of hardness and coercive force as a function of ageing time (t) can be expressed by the Austin-Rickett equation

$$\frac{p}{1-p} = Kt^n$$

where K and n are constants. The activation energies of the ageing were calculated and found to be 74,000–75,600 cal./mole for alloys containing 15–20% Mo.—R. A. R.

Abrasion Fragments—Information Drawn from Their Systematic Examination. J. C. Ceccaldi. (*Usine Nouvelle*, 1953, **9**, Spring Issue, 69–71). The metal fragments collected after abrasion vary greatly in shape but may be sorted into three typical types namely fibres, ' spangles ' and globules found either separately or together. A large proportion of the two latter types indicates a low abrasion efficiency due to fusion of the material ground. A ratio of spangles plus globules to fibres of 1 : 3 corresponds to good efficiency.—A. G.

Tribometer Tests for Determining the Coefficient of Friction of Metals. A. K. Chertavskikh and V. I. Ryesva. (*Zavodskaya Laboratoriya*, 1950, **16**, (8), 1017–1018). [In Russian]. A description is given of a modified form of tribometer and its use for finding the coefficient of friction of a ball-bearing steel against nickel and copper.—S. K.

Wear Resistance Property of Chromized Low Carbon Steel. S. Ueda. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 55–57). [In English]. Chromized steel has good wear resistance properties which, unlike those of chromium-plated steel, do not give rise to a marked increase of wear loss after long attrition. The properties are considerably influenced by concentration gradients in the chromized layer.—K. E. J.

Some Analyses on the Electro-Polished Surface. F. Hayama. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 52–54). [In English]. Some results are given for optical testing of surface smoothness, and for coefficients of friction of electro-polished oil-quenched carbon steels.

Ageing Tests on Permanent Bar Magnets at Different Temperatures. K. Kronenberg. (*Arch. Eisenhüttenwesen*, 1953, **24**, Sept.-Oct., 441–446). Results are reported on the change with time of the apparent remanence of bar magnets of cast and sintered AlNi-120, AlNiCo-400 with preferred orientation, and cobalt steel Co-040, and of plastic bonded Al-Ni base material at temperatures between 500° and −190° C. In contrast with martensitic magnets, the structural ageing of which is considerable, Al-Ni base magnets show no structural ageing provided that they are not heated to too high a temperature. This allows the magnetic ageing to be studied separately. Magnetic ageing proceeds as a linear function of the logarithm of time, in accordance with the theory of Néel.—J. P.

On the Anomaly of Specific Heat at High Temperatures in α-Phase Alloys of Iron and Chromium. H. Masumoto, H. Saitô, and M. Sugihara. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1953, **A, 5**, June, 203–207). [In English]. A variety of alloy compositions were examined in various heat-treated states. With $<24{\cdot}31\%$ Cr, the specific-heat/temperature curves showed a maximum due to magnetic transformation, and a second anomalous maximum at approx. 520–560° C. The anomaly is explained by the formation of the Fe_3Cr

superstructure, which may also account for the high temper-brittleness of the alloys.—K. E. J.

Progress in the Use of Ultrasonics in the Detection of Defects. J. Tabin. (*Hutnik* (Poland), 1953, **20,** (9), 278–285). [In Polish]. Physical bases for the utilization of ultrasonics in detecting flaws in materials are outlined. Ultrasonic methods used in the detection of defects in metallic objects and trends in their further development are surveyed.—V. G.

Magnetic Materials. G. H. Stearley. (*Mat. Methods*, 1953, **37,** Apr., 115–130). The basic principles of magnetism are very briefly discussed and a glossary of magnetic terms is given. The compositions, properties, characteristics, and applications of magnetic materials are then considered.

Micropowder Magnets. (*Metal Ind.*, 1953, **83,** July 10, 27–29). The importance of particle size in determining the coercive force of magnets made from powdered iron and iron alloys is discussed. The available properties and production of such powders are outlined, and the advantages over steels and ferrites (non-metallics) are considered.—P. M. C.

The Electrical Resistivity of Liquid Iron. R. W. Powell. (*Phil Mag.*, 1953, **44,** July, 772–775). The resistivity just above the melting point was found to be 139/microhms/sq. cm./cm. In solid iron it is 127·5 microhms/sq. cm./cm. at the melting point. The increase on fusion of 9% is less than is expected theoretically.—K. E. J.

Ultrasonic Testing Improved with use of Liquid Coupling. J. B. Morgan. (*Iron Age*, 1953, **172,** Aug. 6, 131–135). A special coupling device is described. This consists of a liquid column supported in a plastic cylinder with or without metal diaphragms. This method combines the advantages of contact and immersion test methods; crystal wear is practically eliminated, and rough surfaces can be uniformly inspected. Defects as close as $\frac{1}{8}$ in. to the surface can be detected under suitable conditions.—A. M. F.

Industrial Uses and Applications of Radioactive Isotopes. E. N. Shaw. (*Sheet Metal Ind.*, 1953, **30,** Aug., 645–654, 680). A general account is presented of the properties of radioactive materials, the properties and detection of radiations, statistical fluctuations, tracer techniques, gauging techniques, shape control, gamma radiography, and an ion anemometer.—P. M. C.

Techniques Used in Measuring Uniformity of Materials with Gamma Radiation. J. N. Harris and L. R. Megill. (*Non-Destructive Test.*, 1953, **11,** July, 9–13). The measurement of variations in density or thickness by the absorption of gamma radiation is described. The principles of the method and the properties and suitability of sources such as $cobalt_{60}$, $tantalum_{182}$, $cesium_{134}$, and $selenium_{75}$ are discussed. The design of detectors, and the necessary mechanical devices for traversing the material under examination are dealt with. Records are shown which indicate that variations of 0·001% in mass per unit area can be detected in $\frac{1}{2}$ in. of uranium, 1 in. of iron, and 3 in. of aluminium.—P. M. C.

Automatic X-Ray Film Processing Unit. (*Metallurgia*, 1953, **48,** Aug., 99–100). The automatic film processing unit marketed by Nucleonic and Radiological Developments Ltd., is described in detail. The input end of the unit is in the darkroom, and the output end in the viewing room thus making the films available for an early inspection. The films are carried through the unit on belts.—B. G. B.

Non-Destructive Testing of Large Steel Forgings. P. Bastien. (*Iron Coal Trades Rev.*, 1953, **167,** Sept. 25, 717–723; Oct. 2, 793–797). The author discusses the potentialities and limitations of current non-destructive methods of testing large steel forgings, dealing with dye-penetrant tests, magnetic crack detection, radiography, and ultrasonic testing. Possible sources of error and the correct interpretation of results are considered in detail, and possible future applications are outlined.—G. F.

High-Temperature Alloys—A Bibliography. T. A. Hood. (*Defence Research Laboratories* [Australia], Apr., 1953, *Information Circular* 17). This bibliography contains a comprehensive list of abstracts of papers (1946 to 1950 inclusive) on high-temperature alloys used in gas turbines. There is a subject index and a list of trade names of alloys.—R. A. R.

How to Reduce Failures in High Temperature Alloys. W. E. Jones. (*Iron Age*, 1953, **172,** July 9, 137–141). High-temperature failures can occur from stress rupture which is accentuated by cold work involved in cutting, grinding, and polishing. To reduce this tendency, nickel-base alloys should receive an electrolytic polish as the final operation. Fatigue strength is another factor, and if the ratio of alternating stress to static stress is high, wrought materials offer advantages. For thermal shock, wrought materials of fine grain size are suggested.—A. M. F.

Creep Testing in Compression for Simpler Creep Assessment. A. H. Sully. (*Product Eng.*, 1953, **24,** Apr., 150–153). The design of a creep testing apparatus for use in compression is described. A lever loading type of machine with 10 : 1 ratio is used, and the deflection is measured by a dial gauge. With recrystalized push rods temperatures up to at least 1850° F. can be used and strain rates as low as 2×10^{-6} in./hr. can be measured. There is good correlation between compression and tension tests in the steady creep state up to the onset of accelerating creep provided that the deformations are small.

Investigations into the Influence of Notches on Creep Strength at High Temperatures. W. Siegfried. (*Amer. Soc. Test. Mat. Spec. Tech. Publ. No.* 128, 1952, 93–130). The results of a detailed investigation into this problem are considered. Embrittlement phenomena may occur in austenitic steels at elevated temperatures which depend on the duration of the test to rupture and are to a large extent due to precipitation processes. The strength of the grain boundaries also plays an important part in the development of embrittlement.

Theory of Time-Dependent Rupture and Interpretation of Some Stress-Rupture Data. D. N. Frey. (*Amer. Soc. Test. Mat. Spec. Tech. Publ. No.* 128, 1952, 131–137). Time-dependent rupture is considered as two types of process. At short times and high stresses, rupture is flow-induced and at long times and low stresses (where creep is negligible), it is of a truly brittle nature. The results of experiments carried out in support of these theories are discussed.—B. G. B.

Recovery and Creep in an Alloy Steel. H. A. Lequear and J. D. Lubahn. (*Amer. Soc. Test. Mat. Spec. Tech. Publ. No.* 128, 1952, 163–179). By interrupting a creep test and observing that the creep rate is higher afterwards than before by amounts increasing with the duration of the interruption, it is possible to establish that recovery (reduction of the amount of strain hardening) has occurred. Recovery occurs in quenched and tempered Cr–Mo–V steel at 1000° F., but not at 800° F. When recovery occurs, the plastic creep rate becomes constant. When recovery does not occur, the plastic creep rate decreases continuously. Recovery does not cause creep, as pronounced creep occurs at temperatures where no recovery takes place.—B. G. B.

An Experimental Study of the Strength and Ductility of Steel at Elevated Temperatures. J. Glen. (*Amer. Soc. Test. Mat. Spec. Tech. Publ. No.* 128, 1952, 184–224). Stress-strain tension tests were carried out on a series of low-carbon steels containing varied amounts of manganese and molybdenum. Similar steels killed with aluminium were also tested. In the absence of manganese and molybdenum a maximum in the stress for a given strain was obtained at about 200° C. When manganese was added a second maximum appeared at 300° C., and with molybdenum at 500° C. These maxima in stress are attributed to the precipitation of carbides during the process of straining. The type of carbide formed depends on the temperature of testing and the alloying elements present.—B. G. B.

Effect of Sigma on Strength and Ductility of 25 Cr, 20 Ni Steel. G. V. Smith and E. J. Dulis. (*Amer. Soc. Test. Mat. Spec. Techn. Publ. No.* 128, 1952, 225–236). The precipitation of the sigma phase in 25/20 Cr–Ni austenitic stainless steel is shown to cause a moderate increase in strength at room temperature, a severe loss in toughness at temperatures as high as 500° F., and a moderate loss of creep-rupture strength at 1300° F.—B. G. B.

The Structure and Properties of Stainless Steels after Exposure at Elevated Temperatures. A. B. Wilder and E. F. Ketterer. (*Amer. Soc. Test. Mat. Spec. Tech. Publ. No.* 128, 1952, 237–249). Several ferritic and austenitic stainless steels were exposed at temperatures of 900° to 1200° F. without stress for periods up to 34,000 hr. The microstructure of a weld and of the parent metal and the tensile and creep rupture properties are discussed.—B. G. B.

Radiation Characteristics of Metals. J. Poggie. (*Product Eng.*, 1953, **24,** Sept., 205–207). Graphical data show the relative effects of surface texture and composition on the radiation characteristics of different metals at elevated temperature. Metals tested include titanium, stainless steel, and nickel alloys. Colour appears to have no detectable effect,

but radiation in the infra-red region is modified by oxidation and surface texture.—A. M. F.

A Test for Measuring Quench Crack Sensitivity of Engineering Alloy Steels. R. D. Chapman and W. E. Jominy. (*Metal Progress*, 1953, **64**, Sept., 67–72). The development of a test procedure to measure the susceptibility of steel to cracking when quenched from various austenitizing temperatures into oil or molten salt, is described. The results of tests carried out on some American alloy steels are discussed.—B. G. B.

High Temperature Fatigue Testing. I. High Temperature Fatigue Machine. A. Hikata. (*J. Mech. Lab.*, 1953, **7**, Mar., 50–56). [In Japanese]. A new machine for the rapid determination of the endurance limit of metals at high temperature operates by alternate bending at 80–120 cycles/sec. A simple electric furnace allows tests at any constant temperature up to 850° C. No accurate alignment of parts is required when setting up the specimen.—K. E. J.

Influence of Condition of Material on the Diffusion of Hydrogen in Unalloyed Steel. H. Schumann and F. Erdmann-Jesnitzer. (*Arch. Eisenhüttenwesen*, 1953, **24**, July-Aug., 353-360). The influence of solid deformation, crystal recovery and recrystallization on the permeability of unalloyed steel sheet and wire to hydrogen has been investigated. Small plastic deformations increase the diffusion rate slightly, but deformations above 30% cause a decrease until, at 70% reduction and above, the diffusion rate is practically zero. On annealing heavily-cold-worked material the diffusion rate increases after recovery, from which it is concluded that dislocations inhibit diffusion of hydrogen atoms. The number and size of blisters after charging specimens cathodically with hydrogen decrease as the permeability increases and increase markedly as the permeability decreases again. The results are explained on the basis of lattice energy variations on deformation and annealing.—J. P.

Effect of Boron on the Overheating Temperature of Steel. J. Field. (*Metal Progress*, 1953, **64**, Aug., 78–83). A number of tests have been carried out on seven basic open-hearth steels. Three were modified with boron in the form of a simple 12%-boron alloy while three others were melted with boron in the form of a complex alloy containing aluminium, titanium, and zirconium in addition to boron. Details of the effect of these additions on the overheating characteristics of the steels are given.—B. G. B.

Certain Metallic Material in Short Supply in the Iron and Steel Industry. A. B. Scott. (*Australian Inst. Metals : Australasian Eng.*, 1953, Apr. 7, 53–62). In Part I the classification and importance of steel scrap to the iron and steel industry are outlined. Scrap identification, segregation, preparation for processing, and utilization are dealt with in detail. Part 2 is concerned with the use of substitute alloy steels to conserve strategic alloying elements, and the use of boron as an alloying element is considered.—P. M. C.

Boron Steels: Principal Properties and Industrial Applications. L. C. Correa da Silva. (*Bol. Assoc. Brasil. Met.*, 1953, **9**, Jan., 109–140). [In Portuguese]. The author reviews known facts regarding the properties of boron steels, including the effects of boron on the critical points, the **S**-curve, hardenability, and on the mechanical properties, and states some industrial applications.—R. S.

Practical and Metallurgical Aspects of the Abrasion Resistance of Martensitic White Cast Iron. K. A. DeLonge and H. A. Hunnicutt. (*Bol. Assoc. Brasil. Met.*, 1953, **9**, Jan., 21–46). [In Portuguese]. It is found that the martensitic structure is the best for abrasion or wear resistance. Data are furnished relating to tests on martensitic white cast-iron crusher balls, drills, and other equipment used in the mining and ceramic industries. Precautions in the production of this type of casting are discussed.—R. S.

Guide for Selectors of Carbon Steel Bars. G. P. Witteman. (*Steel*, 1953, **133**, Sept. 14, 104–107, 113 ; Sept. 21, 131–135 ; Sept. 28, 106–113). The six standard carbon steels which account for over 70% of bar production in the U.S.A. are defined. The effect of carbon, manganese, sulphur, phosphorus, silicon, deoxidizing treatment, and grain size on working properties are described, and figures given. Twelve tables give engineering data for the various grades of bar.

Spheroidal Graphite Cast Iron. (Mond Nickel Co. Ltd., 1953). This booklet reviews the engineering properties and applications of spheroidal graphite cast iron made by the addition of cerium or magnesium to the molten metal. After briefly comparing the properties of this material with those of malleable and flake graphite irons, its engineering properties are reviewed. Chill, centrifugal, and alloy iron castings can be produced with spheroidal graphite structures. The superior strength, ductility, and shock resistance, both as cast and after annealing, are shown to have been utilized in a wide variety of applications.—A. D. H.

METALLOGRAPHY

Recent Advances in the Industrial Uses of the Microscope. H. R. Baines. (Inst. Production Engineers: *Engineer Foundryman*, 1953, **18**, Aug., 47–59). A review is made of developments in microscopy. The phase contract, interference, and polarizing microscopes are discussed and improvements in the metallurgical microscope are described. Steresocopic and measuring microscopes are briefly dealt with.—A. D. H.

Recent Developments in Metallurgical Microscopy. B. Arnold. (*J. B'ham. Met. Soc.*, 1953, **33**, June, 63–78). The principles and techniques involved in the ultra-violet light microscope, the polarized light microscope, phase contrast microscopy, the oblique stop microscope, high-temperature microscopy, and the electron microscope are described. The principles of microscopy, *i.e.*, magnifying power, numercial aperture, resolving power, and chromatic and spherical aberration are outlined in order that the development of the above techniques may be more easily appreciated.—P. M. C.

A Note on the Theory of Phase-Constrast Images. H. H. Hopkins. (*Proc. Phys. Soc.*, 1953, **66B**, Apr., 1, 331–333). Some restrictive assumptions in the simple theory are shown to be unnecessary under certain conditions. The extension of the theory makes possible the study of images of objects showing large variations of optical thickness.—K. E. J.

The Effect of Strain in Objective Lenses Used for Microscopical Examination of Metals under Polarized Light. B. W. Mott and H. R. Haines. (*Proc. Phys. Soc.*, 1953, **66B**, Apr. 1, 302–307). The effect of strain in objective lenses is similar to that of rotation of the analyser from the cross position. Procedures are described for assessing relative strain effects in different objectives, and for compensating for various anomalies due to the effects of stray polarization.—K. E. J.

The Magnetic Circuit in Electron Microscope Lenses. T. Mulvey. (*Proc. Phys. Soc.*, 1593, **66B**, June 1, 441–447).

The Effect of Pole Piece Saturation in Magnetic Electron Lenses. G. Liebmann. (*Proc. Phys. Soc.*, 1953, **66B**, June 1, 448–458).

The Ultrasonic Microscope. S. Ya. Sokolov. (*Doklady Akademii Nauk S.S.S.R.*, 1949, **64**, (3), 333–335). An ultrasonic microscope developed by the author is described. A narrow beam of ultrasonic rays is directed on the object and the rays reflected by it fall upon an acoustic converging lens in whose focus is placed a piezo-electric receiving plate. This plate forms the base of a cathode-ray tube. A narrow beam of cathode rays inside the tube falls on the receiving plate causing secondary electrons to be emitted from its surface. This secondary emission is charged by the action of changes on the inner surface of the receiving plate when ultrasonic rays impinge on it. These changes are amplified and transmitted to the modulating apparatus of a second cathode-ray tube and the intensity of the rays from this tube vary with the variation in the secondary emission, and an image of the object or part of it, will be seen on the screen of the second tube.

A Step Wedge for Sensitometry with the Electron Microscope. J. Hamilton. (*Rev. Sci. Instruments*, 1953, **24**, Apr., 309–312).

The Electron Microscope in Metallurgical Research. R. D. Stacey. (*J. B'ham Met. Soc.*, 1953, **33**, June, 53–62). The reflection, scanning, and specimen-emission types of electron microscope are briefly outlined, and the more common transmission type is described in more detail. Several techniques for obtaining specimen replicas are discussed, and the limitations imposed by the necessity for replicas are considered. Some applications in metallurgical research, such as the study of slip, isothermal transformations, and precipitation hardening are described.—P. M. C.

Surface Testing with the Interference Microscope. W. Illig (*Metalloberfläche*, 1953, **7**, July, A97–A104). After outlining the principles of testing a surface by the formation of interference patterns, an interference microscope produced by Zeiss-Opton is described in detail, typical patterns are illustrated and their evaluation explained.—L. D. H.

A Comparison of the Powder Patterns on a Sample of Grain-Orientated Silicon-Iron with Those Obtained on a Single Crystal. L. F. Bates and A. Hart. (*Proc. Phys. Soc.*, 1953, **66A**, Sept. 1, 813–818). A new pattern not hitherto recorded with a single crystal is described, and conditions for the appearance of three different sets of patterns on polycrystalline and single crystal specimens are noted. Data concerning domain boundary spacings are presented. The results support the view that magnetization processes may be explained in terms of aggregates of suitably orientated single crystals.

A Statistical Theory of Order-Disorder Equilibrium at High Temperatures. P. Schwed and G. Groetzinger. (*J. Chem. Phys.*, 1953, **21**, June, 963–967). An expression for the free energy of a binary cubic alloy undergoing the order-disorder transition is derived by direct evaluation of the configurational partition function.—J. C. B.

Edge Dislocations in Inhomogeneous Media. A. K. Head. (*Proc. Phys. Soc.*, 1953, **66B**, Sept. 1, 793–801). A general method is given by which problems of elastic plane strain in a bimetallic (*i.e.*, having different elastic constants on either side of a plane) medium may be reduced to standard problems of potential theory.—K. E. J.

Segregation Phenomena in Nickel Steels. K. Janssen, E. Houdremont, and W. Jellinghaus. (*Arch. Eisenhüttenwesen*, 1953, **24**, July-Aug., 323–332). Segregation in Fe–Ni and Fe–Ni–C alloys after various heat-treatments has been studied. The investigation provides an example of segregation in steels taking place, without the intermediary of a liquid phase, during an incomplete transformation in the solid state. Segregation deliberately produced in nickel steels are readily visible in microstructures ; particularly prominent is the formation of small amounts of austenite during prolonged annealing between 550° and 650° C. It is known that nickel steels with 5–7% Ni are difficult to heat-treat. More attention should be given to the segregations occurring during transformations in the solid state.—J. P.

Isothermal Time-Temperature-Transformation Diagrams of Common Tool Steels. M. Kroneis, R. Gattringer, K. Ebner, and H. Krainer. (*Arch. Eisenhüttenwesen*, 1953, **24**, July-Aug., 333–351 ; Sept.-Oct., 447). The TTT-diagrams of 24 common alloy tool steels are presented and their value is extended by results of hardenability tests and intermediate stage annealing.—J. P.

Critical Points Unaffected by Magnetic Field. B. M. Aldrich. (*Metal Progress*, 1953, **64**, Sept., 110). The results of some 200 experiments on the heating and cooling of steel specimens in a magnetic field produced no evidence that the temperature of the critical points was influenced by the presence or absence of a magnetic field.—B. G. B.

On the Nature of the Eutectic Graphite in Grey Cast Irons. K. P. Bunin and L. A. Dolinskaya. (*Liteinoe Proizvodstvo*, 1953, **3**, (3), 21–23). [In Russian]. A metallographic investigation of grey cast irons, with special reference to the formation of eutectic graphite is reported. Specimens were prepared from an iron containing 4·3–4·4% C, 0·15% Si, and 0·30% Mn. Melts of 100 g. were heated to 1200–1900° C. and cooled under different conditions. Microscopical investigation of sections of specimens so prepared established that the colonies of eutectic graphite grow from one centre. The crystallization of this type of graphite takes place not simultaneously from a large number of centres, but in successive stages in time and space, and at the same time as the crystallization of austenite.—S. K.

The Effect of Magnesium on the Surface Tension, Supercooling and Crystallization of Austenitic Steel. N. S. Kreshchanovskiĭ and R. P. Zaletaeva. (*Liteinoe Proizvodstvo*, 1953, **3**, (3), 20–21). [In Russian]. After a theoretical discussion of the effect of magnesium on surface tension and crystallization processes of austenitic steel, experiments are described in which it was shown that the corresponding decrease in surface tension leads to easier formation of centres of crystallization and a lesser tendency to supercooling. Specimens of an austenitic chromium–nickel steel (15% Cr, 30% Ni), inoculated with different amounts of magnesium, were used. At 1420–1430° C., surface tension displayed a minimum at 0·2% Mg. The effect of magnesium on the primary crystallization of the steel is illustrated, and heating and cooling curves for the solidification range are given ; These reveal the complete disappearance of super-cooling when the steel contains 0·2% Mg.—S. K.

Isothermal Transformation of Austenite and Partitioning of Alloying Elements in Low Alloy Steels. A. Hultgren and Collaborators. (Kungl. Svenska Vetenskapsakademiens Handlingar, 1953, Series 4, **4**, No. 3). This is an English translation of the paper which appeared in Jernkontorets Ann., 1951, **135**, (8), 403–483. (*See J. Iron Steel Inst.*, 1952, **170**, Mar., 307).—R. A. R.

The Determination of TTT-Curves. M. Casadio. (*Metal. Ital.*, 1953, **45**, May, 163–165). The author considers the use of hot-hardness measurement for determining the start and finish curves for isothermic transformation of the austenite. This transformation is examined by hardness control on a test piece kept in a heat-regulated salt bath, placed on the base of a Rockwell apparatus. A number of S-curves, obtained in this manner, are compared with similar curves obtained by the dilatometric method.—M. D. J. B.

Transformation of Austenite into Martensite at Subzero Temperatures—II. V. G. Vorob'ev and A. P. Gulyaev (*Zhurnal Tekhnicheskoi Fiziki*, 1951, **21**, (10), 1164–1169). [In Russian]. The influence of heat-treatment and cooling rate upon martensite transformation at sub-zero temperatures was investigated. The position of M_3 is the major factor determining the optimum conditions of the cooling treatment.

Effect of Deformation at Low Temperatures on the Properties of Austenitic Stainless Steels. K. Bungardt, R. Oppenheim, and R. Scherer. (*Arch. Eisenhüttenwesen*, 1953, **24**, Sept.-Oct., 423–430). The γ-α transformation in austenitic stainless steels is favoured by deformation at low temperatures and thus steels with unstable austenite have higher strengths than when deformed to the same extent at room temperature. The austenitic transformation is only slightly affected by deformation at room temperature with subsequent cooling to low temperatures. To obtain a given strength, less deformation is required at low temperature (−76° C.) than at room temperature. Deformation at low temperatures will give rise to tensile strengths greater than can be obtained by any amount of cold working feasible at ordinary temperatures. At equal tensile strength, the elongation at fracture of low-temperature deformed unstable austenitic steels is greater than after deformation at room temperature. The reduction of area is independent of deformation temperature. The yield point and tensile strength can be considerably increased by annealing these low-temperature deformed steels at 400° C. Taking an annealing period of 24 hours as a basis, the inverse transformation α–γ begins at 400° C. and is complete at 650° C. Below 650° C., establishment of equilibrium is very sluggish. The occurrence of σ-phase is favoured by the γ-α transformation during cold deformation. The self-passivating limit in H_2SO_4 is not influenced by the γ-α transformation during cold deformation, *i.e.*, in oxidizing corroding solutions, the extent of the useful temperature-concentration field is unchanged. On the contrary, if α solid solution is present in the structure as a result of deformation, there is a much greater corrosive attack when the potential is lowered below the activation potential or raised above the " break-through " potential.—J. P.

Cooling Curves of Cast Iron with Spheroidal Graphite. A. Wittmoser. (*Arch. Eisenhüttenwesen*, 1953, **24**, Sept.-Oct., 431–434). Experiments in which blowhole formation round thermocouple sheaths during solidification of cast iron have shown the correctness of earlier observations as to the shape of the cooling curve of cast iron after treatment with spheroidizing agents, also that it is not experimental conditions but the formation of nodular graphite which is responsible for the difference from ordinary cast iron. A quantitative estimation of the heat evolved during crystallization leads to the conclusion that, with spheroidal graphitic cast iron, the heat of solidification is absorbed not only by the environment but also by endothermic reactions in the freezing melt. This may be explained on the assumption that the nodular graphite is formed from a supersaturated solid solution, since such a mechanism requires a marked diffusion of carbon in austenite.—J. P.

Effect of Hydrogen on the Continuous-Cooling Transformation Diagram for a Manganese-Molybdenum Steel. C. L. M. Cottrell. (*J. Iron Steel Inst.*, 1954, **176**, Mar., 273–282). [This issue].

On the Transformation of the Steel by Rapid Heating. Report III—On the Eutectoid Transformation. K. Yokota and N. Iguchi. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 33–35). [In English]. The temperature of the

Ac_1 transformation is affected by heating rate and steel microstructure. It is elevated when the heating rate exceeds the diffusion rate of carbon atoms arising from supersaturated austenite produced by cementite decomposition.—K. E. J.

Influence of Alloying Elements upon Martensite Transformation Temperatures. V. G. Vorob'ev and A. P. Gulyaev. (*Zhurnal Tekhnicheskoi Fiziki*, 1951, **21,** (10), 1157–1163). The influence of the alloying elements, manganese, nickel, chromium, and molybdenum on the temperature range of the martensite transformation was investigated. For comparison, carbon steels containing from 0·6 to 1·0% of carbon were taken. For the initial and final points of the martensite transformation, the temperatures at which 1% and 99% of martensite had formed were taken. Martensite transformation was followed by magnetic measurements, metallographic analyses, and hardness measurements. The experimental results are presented by graphs.—V. G.

On the Change of Melting Point of Metals and other Substances by Pressure. Y. Chino. (*Proc. Japan Acad.*, 1949, **25,** Jan., 22–23). [In English]. The effect of internal or external pressure on the m.p. of a substance may be elucidated with the aid of the Clausius-Clapeyron equation. The changes in temperature are calculated for 15 metals (including iron) and agree with some experimental results.—K. E. J.

On the Behaviours of Enormously Large Internal Stress Accompanying the Transformation of a Substance. K. Honda. (*Proc. Japan Acad.*, 1949, **25,** Jan., 11–21). [In English]. When a volume change accompanies a transformation, a large internal stress is produced, and irreversible heating and cooling effects arise. The stress can be calculated theoretically, and changes in the transformation point derived from the Clausius-Clapeyron equation. Observed results for transformations in pure iron, Fe–Ni alloys, Fe–Mn alloys, and water agree well with theory.—K. E. J.

Study on High Chromium Steels. I—On the Anomaly of α Solid Solution of Fe-Cr System at High Temperatures. Y. Imai and K. Kumada. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1953, **A, 5,** June, 218–226). [In English]. The cause of the so-called 475° C. brittleness of high-chromium steels was examined in the range 15–35% Cr, using hardness, thermal expansion, electric resistance, magnetic analysis, tensile, and microstructure tests. No clear difference in microstructure resulted from different times of annealing at approx. 500° C. The phenomenon is explained by the formation of a superlattice of Fe_3Cr.—K. E. J.

On the Theory of Austempering of Steels. K. Honda. (*Proc. Japan Acad.*, 1946, **22,** Apr., 84–89). [In English]. Austempering is explained in terms of transformation force and internal lattice resistance arising from depression of the A_1 transformation point. These variables may be incorporated in an equation which also introduces time and temperature. (17 references).—K. E. J.

On the Solid Solutions of Metallic Compounds. I. I. Kornilov. (*Doklady Akademii Nauk S.S.S.R.*, 1951, **81,** (4), 597–600). The problem of the formation of solid solutions of metallic compounds and the general principles which make it possible to predict the formation of such solutions are discussed.—V. G.

Carbide Formation in Alloy Steels During High Tempering. G. V. Kurdyumov and M. D. Perkas. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **87,** (1), 41–43). The process of high temperature tempering of two steels with the compositions C 0·11%, V 1·40%, 1·48% Mn, and C 0·10%, Mo 2·14% was investigated. Specimens of the former were quenched from 1340° C. and of the latter from 1250° C. The hardness after tempering at up to 450–500° C. did not change, but an increase in this temperature led first to an increase in hardness and then a sharp drop. X-ray photograms revealed no trace of cementite. An explanation of the retention of a supersaturated solid solution up to high temperatures in steels containing 0·1% carbon alloyed with vanadium or molybdenum is offered.—R. A. R.

Redistribution of Carbon During Transformation in Bainite Range. L. M. Pevzner, G. M. Rovenskii, and T. D. Kubyshkina. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **85,** (4), 811–814). An X-ray investigation is reported of the carbon content of retained austenite in a hypoeutectoid steel after isothermal decomposition in the bainite range. A Cr–Mn–Si steel with 0·25–0·35% C was used. The difference between this steel after isothermal and after ordinary quenching and tempering is that in the former case large quantities of retained austenite highly supersaturated with carbon, and very little carbide, are present.—R. A. R.

An Electron Diffraction Study of the Surfaces of Fe-Ni Binary System Alloys. T. Nakayama. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 66–67). [In English]. The surface structures did not conform with normal phase rule expectations, particularly the boundary between $(\alpha + \gamma)$ and α regions at 90% Ni. Effects of cooling velocity on the surface phases are described.—K. E. J.

Constitution of the FeO-Fe_2O_3-SiO_2 System at Slagmaking Temperatures. R. Schuhmann, jun., R. G. Powell and E. J. Michal. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197;** *J. Met.*, 1953, **5,** Sept., 1097–1104). The authors have determined the liquidus surfaces in the system FeO–Fe_2O_3–SiO_2 from 1250° C to 1450° C., by microscopical examination of equilibrated and quenched samples. From the results, together with previously published valves, a ternary diagram covering the entire stability range of iron silicate slags has been constructed. Metallurgical applications of this diagram, particularly in copper smelting, are outlined.—G. F.

The Iron/Iron-Phosphide/Molybdenum-Phosphide Molybdenum Phase Diagram. R. Vogel and D. Horstmann. (*Arch. Eisenhüttenwesen*, 1953, **24,** July-Aug., 359–374). Structural investigations have shown that in the Mo–P system, there is a eutectic between molybdenum and MoP. Molybdenum can dissolve 5–7% of phosphorus in the solid state. The phase diagram of the Fe–Fe_2P–MoP–Mo, portion of the ternary system has been established by thermal analysis and microscopic and chemical examination. In this system there is an iron solid solution in equilibrium with the compound MoP, from which it follows that the affinity of molybdenum for phosphorus is greater than that of iron.—J. P.

The Iron/Iron-Silicide/Copper-Silicide/Copper Phase Diagram. R. Vogel and D. Horstmann. (*Arch. Eisenhüttenwesen*, 1953, **24,** Sept.-Oct., 435–440). The above equilibrium diagram has been established by thermal and microscopical methods. There is in the system a closed ternary miscibility gap, the upper and lower critical points of which have been determined. The diagram indicates that iron has a greater affinity for silicon than has copper.—J. P.

Dislocation Nodes in Face-Centred Cubic Lattices. N. Thompson. (*Proc. Phys. Soc.*, 1953, **66B,** June 1, 481–492). Dislocation lines meeting at a point constitute a node. In face-centred cubic lattices a dislocation may split into two partial dislocations. The various possibilities of arrangement at a node, movement of nodes, and behaviour of dislocation lines functioning as Frank-Reed sources are discussed.

Presidental Address. F. C. Thompson. (*J. Inst. Metals*, 1953, **81,** Apr., 401–405). In his address to the Institute of Metals on March 24th, 1953, Professor Thompson surveyed the state of metallographic knowledge when the Institute of Metals was formed in 1908.

Apparatus for Crystal Pulling in Vacuum, Using a Graphite Resistance Furnace. K. Lehovec, J. Soled, R. Koch, A. MacDonald, and C. Stearns. (*Rev. Sci. Instruments*, 1953, **24,** Aug., 652–655). A method is described for the formation of large single crystals by pulling seed crystals from a melt in a high-vacuum furnace, in which a graphite crucible and the specimen are rotated. Furnace details and operational procedure are given.—L. D. H.

A Single Crystal Extensometer. A. J. Kennedy. (*Rev. Sec. Instruments*, 1953, **24,** July, 505–507). An instrument is described for measuring extension under constant stress of a single crystal extending under creep.—L. D. H.

CORROSION

The Present and Future Metallurgical Requirements of the Chemical Engineer. Sir Christopher Hinton. (*J. Inst. Metals*, 1953, **81,** June, 465–470). The author surveys materials in use up to 1925 and then deals with the present position regarding materials for the chemical engineer, problems in fabricating chemical plant with particular reference to conditions of oxidizing corrosion and halide attack, and material requirements for atomic energy.—R. A. R.

Recrystallization and the Intercrystalline Corrosion of Mild Steel. Z. Wusatowski. (*Hutnik* (Poland), 1953, **20,** (9), 275–278). [In Polish]. The influence of cold and hot rolling and subsequent heat-treatment on the recrystallization of steel and its relation to the appearance of an intercrystalline

phase is outlined. The causes of intercrystalline corrosion and the influence of intercrystalline phase on the mechanism of deformation are discussed.—V. G.

Cathode-Ray Investigation of the Corrosion of Iron. II. Nature of the "Sharp Ring Substance." R. Uyeda and H. Yoshioka. (*Proc. Japan Acad.*, 1946, **22,** June, 198–199). [In English]. This substance, found in corrosion of cast iron, is the same as "green rust" (hydrated Fe_3O_4), resulting from slow oxidation of the primary corrosion product $Fe(OH)_2$. It is normally produced when oxygen availability is limited. An electrolytic mechanism for its appearance on cast iron is put forward.—K. E. J.

Study of Process of Oxidation (Rusting) of Iron by Isotope Method. E. I. Dontsova. (*Doklady Akademii Nauk S.S.S.R.*, 1952, **85,** (1), 165–167). The distribution of oxygen from the atmospheric phase during the oxidation of iron was studied by oxidizing iron at room temperature in a limited predetermined quantity of standard water with an oxygen isotope-content equivalent to zero, in the presence of oxygen from the atmospheric phase with an excess of the heavy oxygen isotope O_{18}. Where iron oxide deposits occur in a large excess of constantly changing water and in the presence of atmospheric oxygen, there ultimately remains in natural rust that oxygen whose isotope composition corresponds to that of the water.—R. A. R.

Rust Transformers. A. Pollack. (*Metalloberfläche*, 1953, **7,** Mar., B37–B38). After dealing with the limitations of the usual anti-corrosive protective coatings, the author summarizes the characteristics of a coating which would transform existing rust into a chemically passive material, to which a further protective coat could be applied. Examples of the application of this method are given.—L. D. H.

Rust Protection by Painting. E. Sachse. (*Metalloberfläche*, 1953, **7,** June, A93–A96). After giving a brief description of the mechanism of rusting, the author outlines the methods of preparing the iron or steel surface, discusses the most suitable paints and media, and compares the techniques of spraying and brushing.—L. D. H.

Protection of Metallic Surfaces. A. Foulon. *Metalloberfläche*, 1953, **7,** July, A109–A110). Modern methods of protecting metallic surfaces against corrosion are described and compared, and their advantages and drawbacks discussed.

Corrosion of Structural Materials in Water. S. C. Datsko. (*Metal Progress*, 1953, **64,** Aug., 194–200). The results of extensive corrosion tests on stainless steels and numerous non-ferrous alloys in water at temperatures from 70° to 650° F. are reviewed.—B. G. B.

Cast-Iron Pipe Coatings and Corrosion. J. R. Baylis. (*J. Amer. Water Works Assoc.*, 1953, **45,** Aug., 807–831). The author reports on some coal tar coatings inside of pipes in the water system of Chicago. The author classifies the deposits of corrosion products in the pipes into tubercles of different shape, noting how they are formed, and their growth with time. A few short-term corrosion tests are described using ordinary and purified water. The velocity of the water through the pipes has a great effect on corrosion and the type of deposits formed.—J. C. B.

The Atmospheric Corrosion of Architectural Metals. H. P. Godard. (*Eng. J.*, 1953, **36,** July, 844–855). A comparative review is given of data on atmospheric corrosion of metals commonly used in building, viz., aluminium, lead; steel, zinc and galvanized steel. Relative corrosion rates are discussed.

Laboratory Measurements of the Corrosion of Ferrous Metals in Soils. W. J. Schwerdtfeger. (*J. Res. Nat. Bur. Stand.*, 1953, **50,** June, 329–336). A method is described for setting up soil-corrosion cells using a soil-wetting procedure that gives reproducible results. By measuring the weight losses on cell electrodes made of steel and of cast iron after exposure to various soils for six months, it was possible to compare the effects of corrosion on the two materials. It was also found that the electrode weight losses correlated with the weight losses and maximum pitting on wrought ferrous specimens exposed for ten years at the field test sites. Because the laboratory soils covered the range of corrosivity peculiar to soils, it was possible to derive empirical equations for predicting weight loss and pitting at the end of ten years for presumably any soil. It is shown how reasonable adjustments can be made for areas other than that of the field specimens and for exposure periods other than ten years.—R. A. R.

Porosity of Electrodeposited Metals. XI—Analysis of Corrosion Products as a Method of Measuring the Change of Porosity in Corrosion. N. Thon, L. Yang, and S. Yang. (*Plating*, 1953, **7,** Sept., 1011–1015). Some preliminary results are reported of an investigation to determine the change in composition of corrosion products on plated steel as a measure of the increase in porosity of electrodeposits during the course of corrosion. No firm conclusions can be drawn from the results so far obtained, though the method appears to have promise.—J. P.

Coatings and Corrosion Research. (*Product Finishing*, 1953, **6,** June, 74–76, 106). Recent work carried out by B.I.S.R.A. is described briefly. The subjects include: Acid recovery from spent pickle liquors and regeneration from ferrous sulphate; prevention of high temperature scaling of steel by coatings of ammonium borate or clay suspensions; viscosities of pure metals and alloys; porosity determination on tinplate coatings by radio-chemical methods; the production of iron–zinc alloy coatings by electrodeposition; hot-dip aluminizing; zinc recovery from galvanizing dross; the composition and properties of alloy layers formed during hot-dipping; cementiferous paints; the oxides formed on iron when immersed in various passivating solutions; the effect of condensed phosphates and calcium compounds in preventing corrosion of iron in presence of dissolved chlorides; the mechanism of passivating of stainless steel; water-line corrosion; and the effect of the zonal character of wrought iron on its corrosion.—J. P.

A Corrosion Study of Various Chromium Plated Electrodeposits. H. Brown and E. W. Hoover. (*Plating*, 1953, **7,** Aug., 874–878, 838–886). Corrosion results in salt-spray, humidity, and outdoor exposure tests are presented for deposits on steel of nickel, nickel-cobalt, copper, chromium, gold, and rhodium in various combinations. The role of inherent porosity and electrochemically produced porosity is discussed. The use of a thin rhodium deposit between nickel and the final chromium deposit resulted in excellent protection of steel and other metals when exposed to an industrial atmosphere.—J. P.

The Anodic Behaviour of Iron–Chromium Alloys in Sulphuric Acid Solution (1st Report). S. Marioka and K. Sakiyama. (*Tech. Rep. Tôhoku Univ.*, 1953, **17,** (2), 176–189) [In English]. Data concerning passivation and solution are presented for alloys containing 0·30% Cr. Those with >23% Cr showed a second passivation. The formation of the ordered lattice Fe_3Cr reduced anodic dissolution.—K. E. J.

Corrosion of Fuel-Injection Nozzles. W. P. Mansfield. (*Shipbuilder*, 1953, **60,** Sept., 519–522). This investigation was carried out at the British Internal Combustion Engine Research Assoc. laboratory, Slough, in response to complaints of rapid nozzle failure in engines operating overseas. The corrosion was due to the water cooling system cooling the nozzle too much. This permitted rapid attack by the SO_3 present in the gas fumes.—J. C. B.

Water Treatment for Corrosion Control. G. B. Hatch. (*Steel*, 1953, **133,** Sept. 21, 181–188, 194). Iron and steel water systems can be protected from corrosion by removal or neutralization of harmful ingredients, or by adding inhibitors. Substances which are used for both these purposes in open and closed water systems are described.—D. L. C. P.

Corrosion in Water-Cooled Damper Doors at a Steelworks. (*Iron Coal Trades Rev.*, 1953, **167,** Sept. 25, 729–730). An investigation of the failure of water-cooled damper doors in a steelworks' soaking pit has shown that it was caused by restriction of water flow due to corrosive attack on the steel. Addition of a scale-formation inhibitor and sufficient caustic soda to raise the *p*H value of the cooling-water to 9·5 has corrected the trouble.—G. F.

How to Put the Hex on Corrosion of Car Bodies. F. L. LaQue. (*S.A.E. J.*, 1953, **61,** July, 78–80). The corrosive properties of the atmosphere and its dependence on location are discussed with the aid of figures showing corrosivity at various places throughout the world. The variation may be as high as 500 to 1. Ways of preventing corrosion, or of minimizing it, are discussed with special reference to automobile body design.—P. M. C.

Mathematical Studies of Galvanic Corrosion. Part III—Effects of Polarization. J. T. Waber. (*U.S. Atomic Energy Commission Technical Information Service* LA–1386, Mar. 14, 1952). The effects of polarization on galvanic corrosion have been investigated for three practical situations. In each situation, a non-zero value of the polarization parameter k reduces the value of the y-derivative of the potential existing

in the corrodent, and hence the corrosion current, to a finite value. This theoretical result is in agreement with practical experience.—R. A. R.

The Corrosion of Nitrided Stainless Steels in Degassed and Oxygenated Water. H. A. Pray and R. S. Peoples. (*U.S. Atomic Energy Comission, Technical Information Service*, BMI-742, May 1, 1942). Samples of nitrided alloys were coupled with various materials, including Stellite and stainless steel type 410, for 40 days at room temperature, 28 days at 200° F., and for up to one month at 500° F., and the degree of corrosion was studied. The nitrided samples of the 17–4 PH and 322 W alloys (compositions not given) rusted when exposed in degassed or oxygenated water at room temperature and 200° F., but no rust was observed on samples exposed at 500° F.—R. A. R.

Corrosion of Stainless Steels, Especially in Solutions which Cause Pitting. L. Wetternik. (*Maschinenbau u. Wärmewirt.*, 1953, **8,** June, 157–163). The author first outlines the mechanism of attack by corrosive solution, and passivation, and the bearing of passivity on the corrosion resistance of chromium steels. He then discusses pitting in stainless steels, and refers to the use of molybdenum, niobium, and traces of silver for inhibiting pitting. The efiect of halogens is discussed in relation to the use of chlorides as quenching media.—L. D. H.

Cathodic Protection and Magnesium Anodes. B. Raclot. (*Métaux-Corrosion-Indust.*, 1953, **28,** July–Aug., 319–322). The cathodic protection of ferrous metals is described with particular reference to the protection of water pumps. Methods of mounting magnesium anodes at various parts of the pump are illustrated in diagrams of vertical and horizontal pumps. For protection of a vertical pump immersed to a depth of 20 m. in soft water, five 4-kg. magnesium anodes and one 17-kg. anode are sufficient to give protection against corrosion for two years.—B. G. B.

Problems Connected with the Presence of Water in Tubular Structures. M. Scortecci. (*Costruzioni Metalliche*, 1953, **5,** July-Aug., 11–19). [In Italian]. The author examines conditions where water comes into contact with tubular members of structures exposed to the open air, and discusses the two ways in which the tubes suffer damage, *i.e.*, by the external action of frost, and internal corrosion by rust. Results of experiments indicate that the physical behaviour of tubular elements in structures is sound and does not warrant special precautions against the actions of frost or corrosion.

The Delhi Pillar. J. C. Hudson. (*Nature*, 1953, **172,** Sept. 12, 499–500). Corrosion tests on steel and zinc specimens left near the pillar for one year confirm the view that corrosive conditions at Delhi are very mild. This, rather than any intrinsic property, accounts for the excellent state of the pillar.

On High-Temperature Sulphurization of Chromium Cast Iron and Chromium Cast Steel. M. Shiozawa and H. Nakai. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 17–19). [In English]. Tests were made at 900° C. in H_2S to assist improvement of retort materials for CS_2 manufacture. Chromium cast iron was found to be more resistant to corrosion than chromium cast steel, particularly when the chromium content did not exceed 2%. The mechanism of resistance is explained in terms of diffusion and production of a layer of sulphurized, chromium-rich iron.—K. E. J.

The Scaling of Alloys. O. Kubaschewski and O. von Goldbeck. (*Metalloberfläche*, 1953, **7,** Aug., A113–A118). The authors first discuss the classification of oxides by conductivity and the mechanism of oxide diffusion, in the formation of homogeneous oxide layers. The oxidation at high temperatures of steels containing vanadium and molybdenum, the laws governing oxide growth, and the mechanism of heterogeneous oxide formation are dealt with.—L. D. H.

A Study on Causes of Surface Damage on Ship Propellers. E. Galtung. (*J. Amer. Soc. Naval Eng.*, 1953, **65,** May, 389–399). Two mechanisms, proposed to account for the surface wear on ship propellers, are examined. The first is due to cavitation and the second due to electrochemical corrosion. The nature of the oxide film on the metal is considered to have an important bearing on its suitability for propeller construction.—B. G. B.

Scaling Characteristics Make or Break a High Temperature Metal. D. D. Cubicciotti. (*Iron Age*, 1953, **171,** May 21, 144–146). Oxidations are classified by the form of the curve representing the amount of reaction as a function of time. The most common types are linear, and parabolic or logarithmic. The first gives a non-protective coat and the second a protective coat. The logarithmic type is rare and occurs with silicon where the oxide is a glass. The oxidation of germanium has been studied and found to give a combination of the parabolic and linear forms of oxidation rate.—A. M. F.

A Corrected Interpretation of the Mechanism of Growth of Magnetite During Oxidation. M. H. Davis, M. T. Simnad, and C. E. Birchenall. (*Trans. Amer. Inst. Min. Met. Eng.*, 1953, **197 : J. Met.**, 1953, **5,** Sept., 1250). The authors correct a misinterpretation occurring in their earlier work on the mechanism of growth of magnetite during oxidation of wüstite. The result points towards iron ion diffusion in magnetite as the factor controlling growth.—G. F.

"Fretting" and Its Remedy. D. Chambaud. (*Rev. Gén. Méc.*, 1953, **37,** June, 185–187). The results of investigations into fretting corrosion are discussed. Preparation of the surface by shot peening, cyaniding or carburizing increases the resistance to fretting. Normal lubricants are rapidly eliminated from areas where fretting corrosion occurs, but lubricants containing an aluminium-base soap have diminished the rate of corrosion. Plating one of the surfaces with a thin coating of nickel considerably reduces fretting corrosion, and this has been used with success on the bearings of rolling mills.

ANALYSIS

Polarographic Determination of Nickel and Cobalt in Sintered Carbides. K. Protiva. (*Chemické Listy*, 1953, **47,** (7), 1095–1097). [In Czech].

The Analysis of Cobalt. (*Chem. Age*, 1953, **69,** July 11, 77–80 ; July 18, 125–128). This review summarizes recent development in the determination of cobalt and its detection in solution. Organic and inorganic reagents, and physical detection methods are discussed.—J. C. B.

Determination of Carbon in Iron and Steel and Sulphur in Solutions (by Spectroanalysis). O. V. Blank. (*Izvestiya Akademii Nauk S.S.S.R.*, Seriya Fizicheskaya, 1945, **9,** (6), 703–706). A spectroscopic method of determining carbon in iron and steel using the 4267Å and 2297Å lines, and sulphur in aqueous solutions using the S II 5454Å line, is described.

Phosphorus in Steel. K. C. Mazumder and M. K. Ghosh. (*Indian J. Phys.*, 1953, **27,** Jan., 11–17). By means of the medium quartz spectrograph and a 20-kVA. transformer, the spectral lines of phosphorus in steel were photographed and its contents evaluated. The accuracy was fairly good, and it is suggested the inaccurate results were due to segregation.

Polarographic Determination of Zinc in Alkaline Zinc Plating Solutions. R. Diaz and E. H. Lindemann. (*Plating*, 1953, **7,** July 762–764). A 1-ml. portion of the solution is heated to incipient dryness with 1 ml. of HCl and dissolved in water. Gelatin (5 ml. of a 1% solution) is added and the whole made up to 500 ml. A portion of this solution is diluted to twice its volume with 2*M* potassium chloride and polarographed between −0·6 and −1·3 V. *versus* saturated calomel electrode. The zinc content is determined by comparing the wave height with a previously prepared calibration curve. Accuracy claimed is ±2%.—J. P.

Determination of Columbium in the Presence of Titanium. V. S. Syrokomskii and N. G. Klimenko. (*Zavodskaya Laboratoriya*, 1947, **13,** (9), 1035–1038). A quantitative determination of niobium in the presence of titanium, based on differential hydrolysis is described. It is claimed that the analysis can be completed in the course of one working day with satisfactory results. The analytical procedure is given.—V. G.

Carbon Monoxide: Its Detection in Industrial Atmospheres. L. T. Minchin. (*Iron Steel*, 1953, **26,** Sept., 425–426). The author describes a simple portable apparatus for the detection and estimation of carbon monoxide in industrial atmospheres. A double aspirator is used to draw a known quantity of air through a tube containing silica gel impregnated with a palladium salt, the length of the dark stain produced indicating the CO concentration.—G. F.

New Chemical Laboratories: Additions to the Edgar Allen Research Division. (*Iron Steel*, 1953, **26,** Oct., 487–488). This article describes the new extension of the Research Division of Edgar Allen and Co., Ltd., which houses the equipment and personnel for chemical investigations. The layout of the new laboratories, their administration, and the routine are outlined.—G. F.

Apparatus for Micro-Analysis of Gases. A. A. Dobrinskaya, M. B. Neiman, and E. A. Andreev. (*Zavodskaya Laboratoriya*,

1950, **16,** (8), 934–938). [In Russian]. Gas volumes of the order of 0·5 ml. can be measured with an accuracy of 1% in the apparatus described. Satisfactory results have been obtained in the determination of gases in metals.—S. K.

Analyses of Gases Contained in Iron and Steel by Mass Spectrometer. E. Kato. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 68–70). [In English]. The apparatus and its accuracy are described. Results are given for gases from welded portions of enamelled mild steel, and from 18/8 stainless steel at various stages of steelmaking.—K. E. J.

A Carbon-Resistance Furnace for the Determination of Gases in Steel by the Vacuum-Fusion Method. R. M. Cook and G. E. Speight. (*J. Iron Steel Inst.*, 1954, **176**, Mar., 252–256). [This issue].

Determination of Oxygen, Hydrogen, and Nitrogen in Cast Iron. B. B. Bach, J. V. Dawson, and L. W. L. Smith. (*J. Iron Steel Inst.*, 1954, **176**, Mar., 257–263). [This issue].

Advances in the Technical Analysis of Gases and Fluids. H. Engelhardt. (*Trans. Instruments and Measurements Conf.*, Stockholm, 1952, 357–366). [In German]. A survey is made of recent advances in the determination of oxygen in gases by using its paramagnetic properties, analysis of gases by thermal conductivity methods, development of *p*H meters, use of the polarograph, and determination of small amounts of oxygen dissolved in fluids.—L. D. H.

An Oxygen Meter on Magnetic Principles. A. Naumann. (*Trans. Instruments and Measurements Conf.*, Stockholm, 1952, 411–418). [In German]. A detailed account is given of the underlying principles, construction, and method of operation of an oxygen meter utilizing the paramagnetic properties of oxygen.—L. D. H.

Contribution on the Determination of Oxygen as Alumina in Carbon Steels. F. Meunier and P. Flament. (*Rev. Mét.*, 1953, **50,** Sept., 603–616). The three methods available for separating inclusions from alumina-bearing steels, namely attack by acids, anodic dissolution, and solution by iodine in alcohol or bromine in methyl acetate, are reviewed, the last mentioned solvent being preferred. The subsequent photometric estimation of the aluminium after the elimination of other cations is discussed. After reviewing ordinary chemical methods a new method of estimation is proposed enabling both alumina and aluminium nitride to be determined.—A. G.

Photometric Determination of Titanium, with Chromotropic Acid, in Pig Iron and Steel, Including Chromium-Nickel Steels, without Separation of the Iron and the Alloying Elements. W. Koch and H. Ploum. (*Arch. Eisenhüttenwesen*, 1953, **24,** Sept.-Oct., 393–396). Tetravalent titanium forms in acid solution a red-coloured complex with chromotropic acid whereas ferric iron gives a green compound, and ferrous iron a colourless solution. It is therefore not necessary to remove iron from the sample under test, but it must be reduced to the divalent state ; ascorbic acid serves for this purpose. The most suitable *p*H for the estimation is 2·5 and the maximum absorption of the red solution lies between 460 and 480 mμ. The procedure is generally suitable for examining pig iron, and alloyed and unalloyed steels, but those containing vanadium and tungsten necessitate a special calibration curve of the absorption against titanium content.—J. P.

Flame Spectrum Analysis Investigation of Heavy Metals, Particularly for Determining the Ferrite Composition of Steel. F. Wever, W. Koch, and G. Wiethoff. (*Arch. Eisenhüttenwesen*, 1953, **24,** Sept.-Oct., 383–391). During investigations of the composition of electrolytically separated carbides from Cr–Mn steels, it is often desirable to determine rapidly the composition of the ferrite which is dissolved in the alkali citrate electrolyte. A flame spectrum analytical procedure with the necessary sensitivity has been developed which permits the estimation of iron, chromium, and manganese in the presence of large excess of alkali salts. The influence of composition of the electrolyte, the alloying elements in the steel, and the composition of the combustion gases on the intensity of the flame spectrum has been studied.—J. P.

Determination of Aluminium in Iron and Steel. Methods of Analysis Committee. (*J. Iron Steel Inst.*, 1954, **176**, Mar., 263–267). [This issue].

Segregates Determination of Metal Compositions by Spectrographic Analysis. K. Yasuda. (*Waseda Univ., Rep. Castings Res. Lab.*, 1953, June, 63–65). [In English]. Manganese and silicon segregates in cast iron were examined by local spark techniques. The centre point of segregates in a cast cylinder is not always the geometric centre. The effects of cooling velocity and cavities on the dispersion of the elements are discussed.—K. E. J.

Determination of Aluminium and Its Nitride in Carbon Steels. M. Urbain. (*Rev. Mét.*, 1953, **50,** Sept., 617–623). The determination of total aluminium and alumina are briefly described. A method for the estimation of aluminium nitride is outlined and the reproducibility of the method is discussed. The influence of thermal treatments and cooling rate on the nitride content of steels is studied. After quenching from 1200° C. and reheating for 1 hr. at various temperatures, a maximum nitride content is observed when the temperature is 800° C. The effect of the aluminium content in basic-Bessemer steels is examined.—A. G.

Catalytic Analysis XXI—Rapid Determination of Tungsten in Iron and Steel. H. Gotô and S. Ikeda. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1953, **A, 5,** Feb., 37–41). [In English]. A rapid determination of tungsten in iron or steel is based on its catalytic effect on the decoloration of Malachite Green by titanous ion ; it requires approx. 12 min. Molybdenum and vanadium affected the determination, but phosphorus, nickel, cobalt, manganese, and chromium did not.—K. E. J.

Photometric Determination of Arsenic in Steels, Cast Irons, Ferro-Alloys and in Non-Ferrous Alloys. D. Rosi. (*Metal Ital.*, 1953, **45,** May, 166–169). The author establishes the most suitable conditions for applying the Visintin-Gandolfo method of analysis in alkaline solution for determining arsenic. (18 references).—M. D. J. B.

Secondary Spectra X-ray and Chemical Analysis. M. A. Blokhin. (*Zavodskaya Laboratoriya*, 1950, **16,** (8), 941–948). [In Russian]. The spectrograph described is designed for the quantitative determination of elements of atomic numbers 16 to 28 and 42 to 71 ; it embodies some aids to speed and ease of operation.—S. K.

Polarographic Determination of Copper in Steel, Cast Iron, and Ores. N. V. Tananaev, K. A. Matveeva and A. B. Dyukov. (*Zavodskaya Laboratoriya*, 1950, **16,** (8), 1003–1004). [In Russian]. The determination of copper in concentrations of 0·03 to 0·6% in steels, irons, magnetites, and sinters by a polarographic method is described. A determination takes less than 40 min.—S. K.

Determination of Manganese, Chromium, and Vanadium in High Alloy Steels by Amperometric Titration. E. I. Grenberg and M. Ya. Genis. (*Zavodskaya Laboratoriya*, 1950, **16,** (8), 1002–1003). [In Russian]. The application of an amperometric method to determine manganese, chromium, and vanadium in high alloy steels is described.—S. K.

Semi-Microchemical Method for the Determination of Copper in Cast Iron. E. Ya. Shmulevich. (*Zavodskaya Laboratoriya*, 1950, **16,** (8), 1010). [In Russian]. A semi-micro variation of the thiosulphate colorimetric determination of copper in cast iron is described, the sample weighing only 0·2 g.—S. K.

Notes on the Determination of Sulphur in Steels with High Nickel Contents. K. Swoboda. (*Radex Rundschau*, 1952, (7), Dec., 299–302). A survey of various methods was carried out and results are reported. For practical rapid determinations, combustion in an oxygen stream with an addition of tin can be used if great accuracy is not required. Otherwise the reduction method is recommended with subsequent iodometric titration. For series determinations, the hydrogen is best swept out of the reduction chamber by means of an inert gas, *e.g.*, argon.—E. C.

A Rapid Method for the Semi-Quantitative Spectrographic Analysis of a Wide Range of Materials. F. T. Birks. (*Atomic Energy Research Establishment, C/R* 1177, May 6, 1953). The material, without any pretreatment, is arced in graphite electrodes with a covering layer of graphite powder. The photographic region 2000–8000Å. is covered in a single exposure by the use of Ilford Long Range Spectrum Plates in the Hilger medium quartz spectrograph.—R. A. R.

Symposium on Continuous Analysis of Industrial Water and Industrial Waste Water. (*Amer. Soc. Test. Mat., Spec. Tech. Publ. No.* 130, June 24, 1952). This publication contains the papers, with discussions, presented at the A.S.T.M. Symposium held in New York on June 24, 1952. The papers of interest to the steel industry were :

Automatic Sampling of Industrial Water and Industrial Waste Water. M. F. Madarasz. (3–11).

Some Practical Aspects of the Measurement of *p*H, Electrical Conductivity, and Oxidation-Reduction Potential of Industrial Water. R. Rosenthal. (12–22).

Measurement of Color, Turbidity, Hardness, and Silica in Industrial Waters. F. C. Staats. (33–41).

Continuous Measurement of Dissolved Gases in Water. J. K. Rummel. (42–54).

HISTORICAL

The First Iron Works Restoration. (*First Iron Works Assoc. in co-operation with Amer. Iron Steel Inst.*, 1953). This 30-page booklet describes the history of iron making at Saugus, Massachusetts. This works was the product of the initiative of John Winthrop, with several others, about 1641. The furnace, water-wheel, and forge have been restored. An account of the Hammersmith 1643–1675 by Prof. E. N. Hartley is included.—R. A. R.

Steel Manufacture in the Middle Ages a Contemporary Presentation by Vanuccio Biringuccio (1540). P. Koenig. (*Giesserei*, 1953, **40,** Oct. 1, 533–535). An invaluable pyrotechnic handbook of 1540 "*Pirotecnia o sia dell'arte della fusione o getta de metalli*" the work of Vanuccio Biringuccio, is reviewed. A sketchy presentation is given of Vanuccio Biringuccio's personality ; the extent of his principal works (including 10 books on metallurgy) is described and illustrated by considering in more detail the work on steel manufacture.

History of the Manufacture and Use of Die Blocks. F. J. Somers. (*Metal Treatment and Drop Forg.*, 1953, **20,** Aug., 369–375). Following a brief review of the origin and development of drop forging from 1850 to 1900, the compositions and heat-treatment of die block steels are traced up to present day practice. A brief description is given of the mechanised die block production plant at Walter Somers Ltd., Hales Owen.

ECONOMICS AND STATISTICS

Manganese in the Iron and Steel Industry. (*Organisation for European Economic Co-operation*, 1953). The use, recovery, and supply of manganese in the European countries producing steel are surveyed. Annexes give brief descriptions of methods employed in the U.S.A. and Europe for the recovery of manganese.—R. A. R.

The Swiss Iron and Steel Industry. (*Brit. Iron Steel Fed. Monthly Stat. Bull.*, 1953, **28,** Apr., 7–14). The state of the Swiss iron and steel industry and its economic background are briefly reviewed.—V. G.

The Importance of Electric Power in the Supply of Energy to the Swedish Iron and Steel Industry. A. Améen and V. Lanner. (*Jernkontorets Ann.*, 1953, **137,** (8), 261–368). [In Swedish]. The present and future production, consumption, and costs of Sweden's electric power are discussed and electric power as part of the energy supply to the Swedish steel industry is analysed. A forecast is made up to 1972. The economics of different applications are compared.—R. A. R.

The Netherlands Wire Industry. (*Wire Prod.*, 1953, **2,** Aug., 7–8). Statistics of the Dutch wire industry are quoted for 1946–1950. These give the number of firms engaged and the output in various branches of the industry.—J. G. W.

MISCELLANEOUS

Catalogue of Irons and Steels for Research Purposes. (*B.I.S.R.A., Sheffield*, Nov., 1953, MG/226/53). This 75-page catalogue is an enlarged and revised edition of paper MG/302/50. It lists the stock of irons and steels which has been built up with the object of providing materials for research workers with a minimum of delay. About 50 tons of material is in stock, of which 15 tons are reserved for certain B.I.S.R.A. projects.—R. A. R.

The New Research Laboratories of Murex Limited, Rainham, Essex. G. L. Miller. (*Murex Rev.*, 1953, **1,** (12), 281–297).

Applications of Statistical Methods in Research. M. R. Cave. (*Doc. Mét.*, 1953, Apr.-May-June, 68–74). A brief exposition is given of methods of verifying that a distribution follows a given law, and of testing the homogeneity of a set of results.

Training for Science and Technology. Sir Richard Southwell. (*J. Roy. Soc. Arts*, 1953, **101,** Oct. 2, 794–802).

Lightening Manual Work in Iron and Steel Plants as a Rationalization Problem. H. Spitzer. (*Stahl u. Eisen*, 1953, **73,** Oct. 8, 1322–1329). Even in a mechanized plant, productivity and quality still depend to some extent on the efficiency of the manual workers. The conditions, particularly those involving heavy muscular labour or operating in hot places, which can lead to loss of efficiency and methods for counteracting them are discussed.—J. P.

Working and Living Conditions of Workers in the American Iron and Steel Industry. K. Theis. (*Stahl u. Eisen*, 1953, **73,** Oct. 8, 1330–1337). The author gives his impressions of a three months' tour of iron and steel works in U.S.A. and discusses the output, wages, working conditions, and living standards of the American worker as compared with the worker in Europe.—J. P.

Climatic Conditions in Hot Works. L. Oppl. (*Hutnik* (Prague), 1953, **3,** (7–8), 176–178). [In Czech]. It is shown that to obtain optimum working conditions not only temperature but also humidity and movement of air currents have to be measured and controlled. The criteria for optimum conditions are given, and instruments suitable for measuring the relevant variables are discussed.—P. F.

The Formation and Prevention of Atmospheric Contamination in Factories. W. A. Attwood and W. B. Laurie. (*Manchester Assoc. Eng., Advance Copy*, Oct. 16, 1953).

The Problem of the Dry Separation of Dust. H. Anders. (*Glückauf*, 1953, **89,** Sept. 26, 1010–1012). The author first discusses the mathematical laws governing the separation of dust particles falling freely in air, and carried horizontally in a stream of air, and applies the laws to the beneficiation of coal dust. He then discusses the advantages of centrifugal and electrostatic filters.—L. D. H.

Treatment of Water for the Iron and Steel Industry. A. J. Lamb and A. H. Waddington. (*J. Iron Steel Inst.*, 1954, **176,** Mar., 291–302). [This issue].

The Treatment of Water Effluent from Metallurgical Industries. M. Reignier. (*Rev. Tech. Luxembourg*, 1953, **45,** July-Sept., 157–165). Operations which give rise to effluent which is unsuitable for disposal into rivers are described. These include the quenching of coke, the granulation of slag, gas cleaning, rolling-mill cooling water, and coke-oven operation. Typical analysis of the effluent from these operations are given and methods of treatment are discussed.—B. G. B.

BOOK NOTICES

AITCHISON, LESLIE, and WILLIAM I. PUMPHREY. "*Engineering Steels.*" A Study of the Properties of Steels and the Principles Governing their Selection for Engineering Applications. 8vo, pp. 1000 (approx.). Illustrated. London, 1952 : Macdonald and Evans, Ltd. (Price £5 5*s.*)

From the start let it be stated that this is a worthy book, one to be studied by every engineer and by every metallurgist who has the slightest interest in the application of metals. There is so much of value in it that it is difficult to describe its scope without becoming tedious with detail—which the book never does. The sub-title sums up the field covered : The properties of steel and the principles governing their selection for engineering applications.

It is important to note that "No particular standard of knowledge is assumed to be possessed by the reader, certainly no knowledge of metallurgical theory." This makes the book very useful for the vast number of engineers who have not received in their training a formal introduction to metallurgical principles ; in reading it they will certainly learn some sound, practical, ferrous metallurgy, allied to engineering.

The authors start by outlining the different methods of steelmaking and follow this with a more detailed account of the casting of steel ingots and the hot-working of steel. There are also general chapters on the following aspects : Heat-Treatment, Mechanical Testing and Mechanical Properties, Hardenability and Its Application, Surface Hardening, Steel Castings, Welding and Brazing, Machinability, Scrap Recovery, Corrosion and Protection. The actual metallurgy of the various steels is covered by chapters entitled : Plain Carbon Steels, Alloy Steels, Cold-Worked Steels, Tool Steels, Stainless, Creep-Resisting and Heat-Resisting Steels. The foregoing indicates how comprehensively the authors have dealt with the subject. The

text is well illustrated, including a number of good photo-macrographs and micrographs.

In the last chapter, a summary entitled "The Heart of the Matter" the way in which the authors contrast the facts about steel with the engineer's assumption of "a homogeneous isotropic continuum" is masterly. Too many metallurgists do not know enough about the actual application of the metals they produce for the engineer, or of his language and way of thinking, whilst engineers are often woefully ignorant of the metallic state; the skilful way in which the two subjects have been brought together is very valuable. Every engineering student should read this chapter, although one would be wary of recommending the book for general student reading because of its size. Suitably expanded, this chapter would be well worth printing as a separate essay.

Finally, there are a number of useful appendices dealing with all sorts of relevant matter. The index is suitably detailed and the volume is well got up. It makes not only a readable book but a very fine reference work. For this clear and sensible exposition about steel, metallurgists and engineers particularly will have much for which to thank the authors.—A. R. BAILEY

BERNAL, J. D. "*Science and Industry in the Nineteenth Century.*" 8vo, pp. xi + 230. Illustrated. London, 1953: Routledge and Kegan Paul, Ltd. (Price 12*s.* 6*d.*)

The inter-relation between science and industry is a subject of perennial and particularly of current interest. Professor Bernal has given considerable attention to this aspect of human endeavour, and in the present book he is concerned with the nineteenth century, when so many developments occurred in industry. The small volume really comprises two essays. The first deals with the title matter on a general basis, illustrated by specific reference to Heat and Energy, Ferments and Microbes, The Age of Steel, and Electric Light and Power. The second essay is very specific and analyses in detail the discovery of molecular asymmetry by Pasteur.

To metallurgists, the survey in the first essay will be interesting both from the overall aspect and because developments in steelmaking are discussed. It is especially interesting to note the author's judgement on the work of Bessemer, Siemens, and Thomas. He concludes that their successes in developing new processes were due to their clear appreciation of the problems, and to the fact that they were not metallurgists. Thus, instead of thinking in terms of modifying existing practice they applied themselves boldly to solving new methods.

The interest in the second essay lies not so much in the actual subject matter of the discovery, although "one of the greatest of the nineteenth century", but more in the vivid reconstruction of the process of the discovery. The author shows how the evidence for the discovery came from industrial as well as scientific sources, and he traces out its far-reaching consequences. Interest is increased because the author has been able to draw on Pasteur's original and unedited notebooks, from which extracts are reproduced.

The book is refreshing to read and the pages are of pleasant appearance. However, although one appreciates the reason for the author's footnotes, now that they are included, they do distract from smooth reading on those pages on which they appear.—A. R. BAILEY

CONWAY, C. G. "*Heat-Resisting Steels and Alloys.*" A concise Data Book giving the high-temperature properties of commercial steels and alloys. 8vo, pp. vii + 160. Illustrated. London, 1953: George Newnes, Ltd. (Price 25*s.*)

This small book of very handy size has been written to provide a ready reference to available information regarding materials for service at elevated temperatures, and it will prove very useful to designing engineers, whether they are interested in steam plant, jet engines, gas turbines, or furnace construction. Over the last 25 years or so many data have been published either in technical papers or in manufacturers' brochures; by collecting this information into one data book the author has made the material much more readily accessible.

Apart from creep, data are given on various physical properties such as thermal conductivity, thermal expansion, and Young's modulus, which are important factors in the use of materials at such temperatures. It is somewhat surprising that no information is given about resistance to fatigue, which may, of course, be important in certain components. It would also be an advantage if a little more precise information were given on the scaling resistance of the different steels, so that the user might have a clear idea of the upper limit of service temperature imposed by this criterion. Thus, it is not sufficient to say that a 20/25 Cr–Ni steel is less resistant to oxidation than a 25/20 Cr–Ni steel; the actual temperature at which scaling becomes severe should be stated.

The creep data are presented both in the form of tables and in graphs. Most of these graphs are clear and well drawn, but in one or two cases, *e.g.*, Figs. 24 and 25, the lines showing the stress levels are too widely spaced, so that reasonable estimates of the stress for a particular creep criterion and temperature are difficult to make with reasonable precision (compare, for example, with Figs. 19 and 20).

For the purpose of easy reference the book is divided into sections covering the following categories of steel: Carbon and low-alloy steels; bolt steels; valve steels; heat-resistant casting alloys; austenitic steel of standard type; and special heat-resisting steels and alloys of proprietary type (*a*) for iron-base alloys, and (*b*) for nickel-base alloys. The first of these sections comprises low- and medium-carbon steels, C–Mo, Mo–V, Cr–Mo and Cr–Mo–V up to 3% Cr, 3% Ni–Cr–Mo and 3%Ni–Cr–Mo–V steels, as well as plain chromium steels up to 27% Cr—the latter can hardly be called low-alloy. Although there is a separate section for bolt steels, some of the steels in the carbon and low-alloy steel section are used for high-temperature bolts; a separate section for bolt steels is, however, justified, for in this section some data on relaxation are given.

In a brief note at the commencement of each of these sections the author writes:

> "Since the creep properties of steels and alloys vary from one heat of steel or alloy to the next, it is advisable to consult the manufacturer before ordering material to perform at a high duty at a given temperature."

This observation will be welcomed by the manufacturers, who, with their more complete knowledge of their product, are better able to state what these products can withstand than can be indicated in isolated examples quoted in the literature.

The advances in creep-resisting steels and alloys have been so rapid in recent years that it is not surprising that some of the more recent materials are not mentioned, but, although the author apologizes for such possible omissions, one would have expected steels like Nos. 467 and 448 of Firth-Vickers Stainless Steels Ltd., and No. H46 of William Jessop and Sons Ltd. to be included.

There is little to criticize in the creep data, but the reviewer does not agree with the author that 18/8-Nb steel is inferior to 18/8 low-carbon or 18/8-Ti steels in creep resistance, neither do the creep curves given support this contention. No reference is made to important information on these steels given by Kirkby and Sykes in the Symposium on High-Temperature Steels and Alloys for Gas Turbines (Iron Steel Inst., 1952, Special Report No. 43). Although Firth-Vickers introduced the 23/12/3 Cr–Ni–W heat-resisting steel (H.R. Crown Max), only data presented by Jessops have been given; again, an important source of information on this steel is the paper by Morley in the above Symposium.

The author says that all corrections and additional data would be gratefully accepted for future use. This suggests that he hopes to bring out a second and improved edition. The criticisms made above are not intended to decry the usefulness of the book, but to answer the author's own request in the hope that a new edition will be a still more useful publication than this first edition.—J. WOOLMAN

"*Fifth Empire Mining and Metallurgical Congress, Australia and New Zealand,* 1953." Publications, six volumes. 8vo. Illustrated. Melbourne, 1953: Office of the Congress and Australasian Institute of Mining and Metallurgy.

Volume I. "*Geology of Australian Ore Deposits.*" A Symposium arranged by a Committee of the Australasian Institute of Mining and Metallurgy (Inc.) and edited by A. B. Edwards. Pp. xiv + 1290. (Price 84*s.* Australian).

Volume II. "*Mining Methods in Australia and Adjacent Territories.*" Edited by R. Pitman Hooper and A. B. Black. Pp. xv + 374. (Price 40*s.* Australian).

Volume III. "*Ore Dressing Methods in Australia and Adjacent Territories.*" Edited by H. H. Dunkin. Pp. ix + 317. (Price 27*s.* Australian).

Volume IVA. "*Extractive Metallurgy in Australia. Ferrous Metallurgy.*" Edited by J. C. Richards. Pp. xii + 217. (Price 35*s.* 6*d.* Australian).

Volume IVB. "*Extractive Metallurgy in Australia. Non-Ferrous Metallurgy.*" Edited by Frank A. Green. Pp. ix + 272. (Price 25*s.* Australian).

Volume V. "*Australian Mining and Metallurgy. Miscellaneous Features and Practices.*" Edited by A. W. Norrie. Pp. x + 253. (Price 25*s.* Australian).

Volume VI. "*Coal in Australia.*" A symposium Arranged by a Committee of the Australasian Institute of Mining and Metallurgy (Inc.) and edited by a Committee of the Sydney Branch. Pp. x + 832. (Price 60*s.* Australian).

These volumes contain the papers presented at the Fifth Empire Mining and Metallurgical Congress, held in Australia and New Zealand in April, May, and June, 1953. Only Volume I is in its final, bound form, the others being still in the pre-print, paper-backed state ; bound volumes II to VI containing the discussion as well, and Volume VIII, " Proceedings and New Zealand Papers ", will be available late in 1953. Volume VII, " Handbook—Australia and New Zealand ", described as a guide to the geography, geology, history, economy, and general social environment of Australia and New Zealand, with particular reference to the mining and metallurgical industries was distributed at the Congress, but no copy has reached the Library yet.

The papers have been arranged in a number of groups, as will be seen from the titles of the volumes, and together present a comprehensive and detailed picture of the Australasian mining and metallurgical industries. No such meticulous treatment of this important sphere of Commonwealth activity has ever appeared before, and these eight volumes may well be regarded in future years, as the Domesday Book of Australian and New Zealand metal-extraction and treatment. Much of the material will be of great interest to members of the Iron and Steel Institute and abstracts will appear in the *Journal* in due course.

J. P. S.

KOPPENBERG, HEINRICH, and WERNER WENZEL. "*Die Sauerstoffmetallurgie der Schachtofenprozesse.*" 8vo, pp. [xii +] 236 [+ iv]. Illustrated. Düsseldorf, 1953 : Verlag Stahleisen, m.b.H. (Price DM 18.–).

The tone of this book is set by the first chapter heading " The Development of Metallurgical Practice from the Air Age to the Oxygen Age." The authors are enthusiastic advocates of the combination of oxygen-enriched air and the low-shaft furnace, and are inclined to offer it as the nostrum to cure most of the ills of extraction metallurgy. It is probably inevitable that the case should be overstated. The authors are extremely fertile with ideas, many of which are, to say the least, somewhat fanciful, but many are also very thought-provoking. This is most emphatically not a book for the layman, but, read with the necessary background for a critical appraisal, the fresh approach to many problems can be quite stimulating.

In the first chapter the authors discuss the general case for the ' upgrading ' of air by lowering the proportion of inert nitrogen, and show the effect on theoretical flame temperatures. They then apply these principles to the to the shaft furnace and point out some of drawbacks of extremely high flame temperatures in this case, *e.g.*, (*a*) the vertical temperature gradient is steep, so that temperatures in the shaft are low and unfavourable for gas–solid reactions, and (*b*) temperatures in the combustion zone may be high enough to cause volatilization of gangue constituents and subsequent ' hanging ' trouble.

The authors then go on to discuss various means of minimizing these disadvantages, conventional means such as recirculation of top gas or admixture of steam, and less conventional like multiple rows of tuyeres and charging to give a stock column with core and annulus of different physical and chemical properties. This latter is a favourite device of the authors, but, however interesting, the reviewer must confess to many mental reservations as to its practicability.

The discussion on the application to ferrous metallurgy bristles with anomalies, of which only one or two examples can be given. For instance, the authors are rightly concerned to increase efficiency and decrease the required amount of costly oxygen. But to propose recirculation of top gas as one way of doing so ignores the fact that the reduction of CO_2 by carbon at the tuyeres is equivalent to direct reduction. Similarly, it is suggested that steel may be made directly in the low-shaft furnace. The problem of sulphur removal is mentioned, but the fact is ignored that because the impurities (carbon, silicon, etc.) in pig iron raise the activity coefficient of sulphur some four to five times, the problem of desulphurizing steel *vis-à-vis* pig iron is enormously intensified. Another example is to reduce fine ore under pressure, incidentally forming much deposited carbon, which is utilized in the subsequent smelting process. It is then suggested that the reduced ore can be concentrated magnetically, with no mention of what is going to happen to the valuable carbon.

The authors do point out late in the book that high oxygen concentration is the optimum solution if and when the rich top gas can find a valuable use as the raw material for the Fischer-Tropsch synthesis. This, however, is not likely to be economic until natural supplies of oil begin to fail. The real interest of oxygen-enriched blast at present is in the special field of ferro-alloy production, or where high alumina (high-melting) slags suitable for aluminium extraction are a valuable by-product, although it should be noted that the slag composition suggested as most suitable is in a comparatively low-melting region (1350–1400° C.). The importance of the low-shaft furnace (air-blown) lies in the ability to use low-grade fuel. A suggestion that there is an unwanted (from the blast-furnace point of view) range of ore size *circa* ¼ in. to 1 in., which could be smelted in the low-shaft furnace, is unlikely to find much favour among blast-furnace managers. Another suggestion that fine ore might be smelted by deliberately encouraging segregation of the stock column to increase gas permeability is a much more interesting and attractive idea.

J. TAYLOR

PARADINE, C. G., and B. H. P. RIVETT. "*Statistics for Technologists.*" 8vo, pp. vii + 288. Illustrated. London, 1953 ; English Universities Press, Ltd. (Price 25*s.*)

The reviewer's only outstanding criticism is that the book is not for the public that its title suggests. If by " technologists " the authors mean the various sorts of engineer and applied scientist engaged in specialized and executive work in industry, it is unlikely that this book will appeal to them. Although the authors have attempted to steer a middle course between a mere statement of formulæ and methods with practical illustrations, and a full mathematical treatment, even the minimum amount of mathematics demanded by the book will require a degree of concentration on the part of most technologists that will discourage many, through lack of time or of recent practice in mathematical exercises. That it is vital that technologists should acquire a knowledge of statistics nobody will deny, but the reviewer doubts whether the main body of technologists are as yet sufficiently trained mathematically to derive full benefit from a work of even this modest mathematical level.

The exceptional technologist with some knowledge of statistics and a strong desire to know more will find this book valuable, but it is pre-eminently for the man who wishes to become a statistician or a researcher whose work entails a fair amount of statistical analysis. It is an excellent book for mathematical students as a preliminary to more advanced reading. For these classes of reader the book is probably the best value on the market.

The most commonly used techniques of statistics are given with a mathematical apparatus that carries conviction, but probably the most valuable feature of the book is that each important topic is amply illustrated with practical examples which enable the reader to fix each development in his mind. Some are from Royal Statistical Society certificate and other sources, so that the book should be particularly valuable to students preparing for examinations. Lest it be thought that it is a stodgy textbook suitable for cramming purposes, the reviewer hastens to point out that its descriptive writing is lively and lucid.

There are good chapters on sampling inspection schemes and quality control, and the chapter on the analysis of variance is particularly noteworthy. The latter combines

the theoretical with the practical and computational aspects very well. It is perhaps a pity that the succeeding chapter is not one on experimental design instead of probit analysis, although the practical illustrations of this technique are industrial-type examples. There is one general criticism, and that is that the authors have not brought out the basic idea of errors of both the first and second kind. This might be excused on the grounds that the book is for technologists and that the "power of a test" idea is not an easy one, but for the reason given above the reviewer is in disagreement.

The authors are to be praised for the two chapters "Theory of Errors" and "The Theory of Least Squares" which is concerned with much of the work stemming from Gauss and of particular interest to physicists and surveyors. It is rare to see this older work in modern general textbooks, and an artificial division of the subject has arisen.

It is to be hoped that the book will be read widely by students, budding statisticians, and statistically minded technologists.—W. N. Jessop

NEW PUBLICATIONS

Anglo-American Council on Productivity. "*Production Control.*" Report of a Visit to the U.S.A. in 1951 of a Specialist Team on Production Planning and Control. La. 8vo, pp. x + 130. Illustrated. London, 1953 : British Productivity Council. (Price 5*s.*)

Ausschuss für Sozialwirtschaft der Wirtschaftsvereinigung Eisen- und Stahlindustrie. "*Analyse und Bewertung von Angestelltentätigkeiten*". (Sozialwirtschaftliche Schriftenreiche, Heft 5.) Bearbeitet im Fachausschuss "Arbeitstudien, Arbeits- und Leistungsbewertung" vom Hans Euler, Hans Stevens, Fritz Schilling, Rudolf Schoppe, mit einer arbeitspsychologischen Einführung von Erwin Bramesfeld. Folio, pp. 88. Illustrated. Düsseldorf, 1953 : Verlag Stahleisen m.b.H. (Price DM 12·50)

Ausschuss für Sozialwirtschaft der Wirtschaftsvereinigung Eisen- und Stahlindustrie. "*Des Altersaufbau der Belegschaft der Eisen- und Stahlindustrie in der Bundesrepublik Deutschland am 1. December* 1952." (Sozialwirtschaftliche Schriftenreihe, Heft 4.) Bearbeitet von H. Euler. Folio, pp. 81. Illustrated. Düsseldorf, 1953 : Verlag Stahleisen m.b.H. (Price DM 3·60)

British Iron and Steel Research Association. "*Catalogue of Irons and Steels for Research Purposes.*" 2nd edition. Prepared by the Metallurgy (General) Divisional Laboratory. La. 4to, pp. 75. Sheffield, 1953 : B.I.S.R.A. Metallurgy (General) Division.

Brödner, Ernst. "*Zerspanung und Werkstoff.*" Ein Handbuch für den Betrieb. 2. Auflage. 8vo, pp. 256. Illustrated. Essen, 1950 : Verlag W. Girardet.

Chaussin, C., and G. Hilly. "*Métallurgie.*" Préface de P. Chevenard. Tome II. "*Elaboration des Métaux.*" 2e édition. La. 8vo, pp. xiii + 202. Illustrated. Paris, 1954 : Dunod. (Price 880 fr.)

Damerow, E. "*Grundlagen der praktischen Federprüfung.*" 2. Aufl. Pp. 190. Illustrated. Essen, 1953 : W. Girardet. (Price DM 16·80)

"*Gmelins Handbuch der anorganischen Chemie.*" 8. Auflage. System-Nummer 9 : *Schwefel.* Teil A, Lieferung 3 : "*Bildung und Darstellung. Das System Schwefel. Physikalische Eigenschaften. Elektrochemisches Verhalten. Chemisches Verhalten. Nichtwässerige Lösung. Schwefel als Lösungsmittel.*" 8vo, pp. xvi + 511–762. Illustrated. Weinheim/Bergstrasse, 1953 : Verlag Chemie G.m.b.H. (Price DM. 142.–)

Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique des Produits Métallurgiques." 15e *Congrès tenu les* 18, 19 *et* 20 *juin* 1952." La. 8vo, pp. 281. Illustrated. Paris, 1953 : G.A.M.S.

Gumbel, Walter, and Kenneth Potter. "*The Iron and Steel Act,* 1953." With General Introduction and Annotations. La. 8vo, pp. v + 97. London, 1953 : Butterworth and Co. (Publishers), Ltd. (Price 17*s.* 6*d.*)

Hoffman, O., and G. Sachs. "*Introduction to the Theory of Plasticity for Engineers.*" Pp. xiv + 276. Illustrated. New York, Toronto, London, 1953 : McGraw-Hill Book Co., Inc. (Price $6·50)

Hull, J. L., and I. Cornet. "*Plastic Deformation of Metals, Survey of Literature* 1950–1951 *Inclusive.*" (American Iron and Steel Institute, 1952, Contributions to the Metallurgy of Steel, No. 42). 8vo, pp. v + 257. New York, 1952 : The Institute.

"*Jahrbuch der Schleif- und Polier-Technik und der Oberflächenbehandlung.*" Begrundet, hrsgeg. u. bearb. von Bernhard Kleinschmidt. Pp. 343. Illustrated. Essen, 1953 : Vulkan-Verlag Dr. W. Classen. (Price DM 12.–)

John, W. D. "*Pontypool and Usk Japanned Wares.*" With the Early History of the Iron and Tinplate Industries at Pontypool. La. 4to, pp. xii + 88. Illustrated. Newport (Mon.), 1953 : The Ceramic Book Company. (Price 63*s.*)

Lipson, H., and W. Cochran. "*The Determination of Crystal Structures.*" (Volume III of "The Crystalline State," edited by Sir Lawrence Bragg). 8vo, pp. ix + 345. Illustrated. London, 1953 : G. Bell and Sons, Ltd. (Price 50*s.*)

Mielenz, Klaus-Dieter. "*Leitfaden zur Spektralanalyse mit dem Metallspektroskop.*" Mit vollständigen Analysenvorschriften für die quantitative Untersuchung von Stählen, Aluminium und Kupferlegierungen sowie Tafeln und Tabellen für die qualitative Analyse beliebiger anderer Substanzen. 4to, pp. 10. Berlin-Steglitz, 1953: R. Fuess, Fabrik für wissenschaftliche und technische Präzisions-Messinstrumente. (Price DM 48.–)

Mitchell, James. "*Steelmaking Processes Related to Blast-furnace Practice.*" (Fourth Harold Wright Lecture). 8vo, pp. 19. Middlesbrough, 1953 : Cleveland Scientific and Technical Institution.

Moore, Herbert F., and Mark B. Moore. "*Textbook of the Materials of Engineering.*" Pp. 372. New York, 1953 : McGraw-Hill Book Co., Inc. (Price $6)

Naish, William Archibald, John Edward Clennell, and Victor S. Kingswood. "*Select Methods of Metallurgical Analysis.*" Second edition revised. 8vo, pp. xii + 660. Illustrated. London, 1953 : Chapman and Hall, Ltd. (Price 75*s.*)

Organisation for European Economic Co-operation. "*European Foundries and Productivity.*" Some recent experiments and achievements. Technical Assistance Mission No. 122. La. 8vo, pp. 268. Illustrated. Paris, 1953 : The Organisation.

Poetter, Heinrich. "*Hartguss und Walzenguss.*" (Bd. 42 der Taschenausgabe für das Giessereiwesen. Herausgeber Dr. Ing. Gustav Speer.) 8vo, pp. 188. Illustrated. Berlin, 1953 : VED Verlag Technik. (Price DM 8.–)

Richards, C. E., and A. C. Lynch (Editors). "*Soft Magnetic Materials for Telecommunications.*" A Symposium held at the Post Office Engineering Research Station in April 1952. 8vo, pp. viii + 346. Illustrated. London, 1953; Pergamon Press, Ltd. (Price 63*s.*)

Rollefson, G. K. (Editor). "*Annual Review of Physical Chemistry.*" Vol. 4. 8vo, pp. [x +] 493. Illustrated. Stanford, Calif., 1953 : Annual Reviewers, Inc. ; London : H. K. Lewis and Co., Ltd. (Price $6 or 48*s.*)

Schwarzkopf, Paul, and Richard Kieffer. "*Refractory Hard Metals: Borides, Carbides, Nitrides, and Silicides; the Basic Constituents of Cemented Hard Metals and Their Use as High-Temperature Materials.*" In collaboration with Werner Leszynski and Fritz Benesovsky. Pp. 447. Illustrated. New York, 1953 : The Macmillan Co. (Price $10).

The United Steel Companies, Ltd. "*Railway Materials Handbook.*" 8vo, pp. iv + 372. Illustrated. Sheffield, 1953 : The United Steel Companies, Ltd. (Price 21*s.*)

Verein Deutscher Eisenhüttenleute. "*Werkstoff-Handbuch Stahl und Eisen.*" 3., vollständig neu bearbeitete Auflage. Mit dem Werkstoffausschuss des Vereins Deutscher Eisenhüttenleute und zahlreiche Fachgenossen bearbeitet von Dr.-Ing. Karl Daeves. 8vo, looseleaf. Illustrated. Düsseldorf, 1953 : Verlag Stahleisen m.b.H. (Price DM 78.–)

Wang, Chi-Teh, "*Applied Elasticity.*" 8vo, pp. ix + 357. Illustrated. New York, Toronto, London, 1953 : McGraw-Hill Book Co., Inc. (Price 57*s.* 6*d.*)